Musculoskeletal Imaging

Diffuse Bone Diseases

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Differential Diagnosis:

- Osteopenia
- Osteosclerosis

Osteoporosis

Vitamin-deficiency Bone Disease:

- Rickets
- Osteomalacia
- Scurvy

Endocrine Bone Disease:

- Hyperparathyroidism
- Renal osteodystrophy
- Hypoparathyroidism
- Hypothyroidism
- Hyperthyroidism
- Acromegaly

Hematologic Bone Disease:

- Thalassemia
- Sickle cell disease
- Leukemia
- Lymphoma
- Langerhans cell histocytosis (LCH)
- Gaucher's disease
- Metastasis
- Multiple myeloma
- Myelofibrosis
- Mastocytosis
- Myelodysplastic syndrome

Idiopathic bone disease

- Paget disease
- Sarcoidosis

Phakomatosis = Neurocutaneous Syndromes

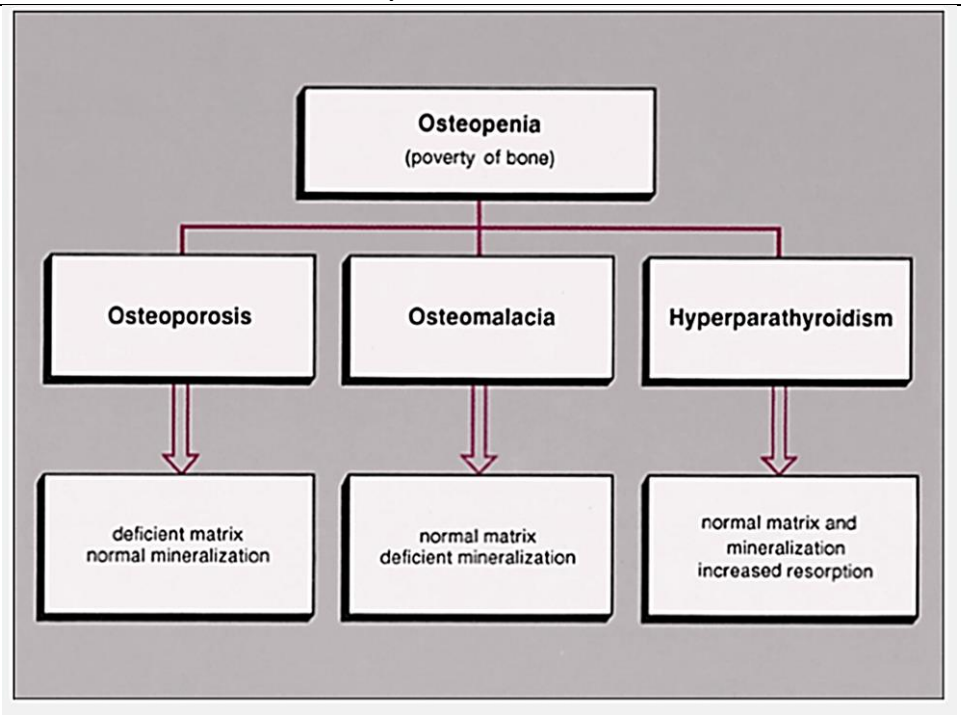
- NF-1
- Tuberous sclerosis
- Nail – Patella Syndrome
- McCune-Albright syndrome
- Nevoid BCC syndrome

Skeletal Dysplasia

❖ DD: Osteopenia

- Osteoporosis
  - Primary
  - Secondary:
    - Endocrine disorders: Cushing syndrome
    - Nutritional disorders: Alcoholism
    - Metabolic or collagen disorders
    - Drugs: Steroids
- Vitamin Deficiency Bone disease
  - Osteomalacia
  - Rickets
  - Scurvy
- Hyperparathyroidism
- BM Infiltration:
  - Multiple myeloma
  - Diffuse metastases
  - Leukaemia
- Anaemia

- Osteopenia is a non-specific radiological finding.
- Indicated increased radiolucency of bone.



❖ DD: Diffuse Sclerotic Bone Diseases

Congenital = Sclerosing bony dysplasia:

- Osteopetrosis
- Pyknodysostosis
- Melorheostsis
- Osteopoikilosis
- Osteopathia striata
- Progressive diaphyseal dysplasia (Engelmann's disease)
- Hereditary multiple diaphyseal sclerosis (Ribbing disease)
- Hyperostosis corticalis generalisata

Idiopathic

- Caffey's disease (infantile cortical hyperostosis)
- Idiopathic hypercalcaemia of infancy

Haematological causes

- Myelofibrosis
- Mastocytosis
- Sickle cell disease

Metabolic bone disorders

- Hyperthyroidism
- Hypoparathyroidism
- Renal osteodystrophy

Poisoning

- Lead
- Fluorosis.
- Hypervitaminosis D
- Hypervitaminosis A

Malignancy

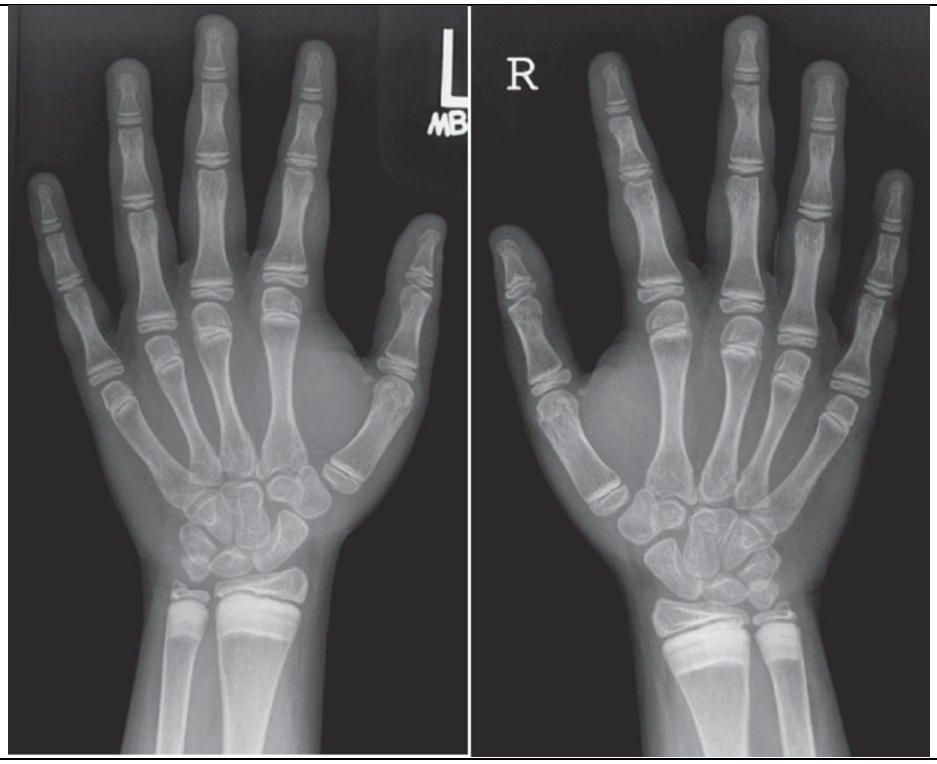
- Lymphoma : infiltration
- Leukaemia : infiltration
- Osteoblastic metastases : e.g Prostate cancer

Other

- Paget's disease
- Hepatitis C associated osteosclerosis (HCAO)

❖ DD: Dense Metaphyseal Bands

- Anaemia : chronic (eg, sickle cell disease; thalassemia)
- Chemotherapy : e.g. Methotrexate
- ***Growth acceleration lines*** following growth arrest due to systemic illness or stress in infancy or childhood : e.g. Asthma; diabetes; cystic fibrosis; juvenile chronic arthritis; juvenile rheumatoid arthritis; malnutrition
- **Lead poisoning**
- **Leukemia: treated**
- **Rickets, healing**
- **Scurvy, healing**
- Normal variant : especially in a neonate - dense zone of provisional calcification
- Renal osteodystrophy (secondary hyperparathyroidism), healing
- Trauma : non accidental injury ; stress fracture



❖ DD: Alternating Radiolucent And Radiodense Metaphyseal Lines

- Growth arrest lines
- Bisphosphonate therapy
- Rickets: especially those on prolonged treatment, e.g. Vitamin d dependent rickets
- Osteopetrosis
- Chemotherapy
- Chronic anaemia: e.g. Sickle cell anaemia and thalassaemia
- Treated leukaemia

❖ Erlenmeyer flask deformity

Marrow infiltration/expansion

- Thalassaemia - coarsened trabeculation, cobweb appearance
- Sickle cell disease
- Lysosomal storage disease
- Gaucher disease - osteopenia with legg-calvé-perthes disease or hass disease
- Niemann-pick disease
- Haemoglobinopathies

Bone dysplasias

- Fibrous dysplasia
- Osteopetrosis - diffuse sclerosis and sclerotic vertebral endplates (sandwich vertebrae)
- Craniometaphyseal dysplasia
- Metaphyseal dysplasia - pyle disease
- Sclerotic diaphysis
- Achondroplasia
- Ollier disease
- Multiple hereditary exostoses

Bone Marrow

To recognize the

Abnormal,

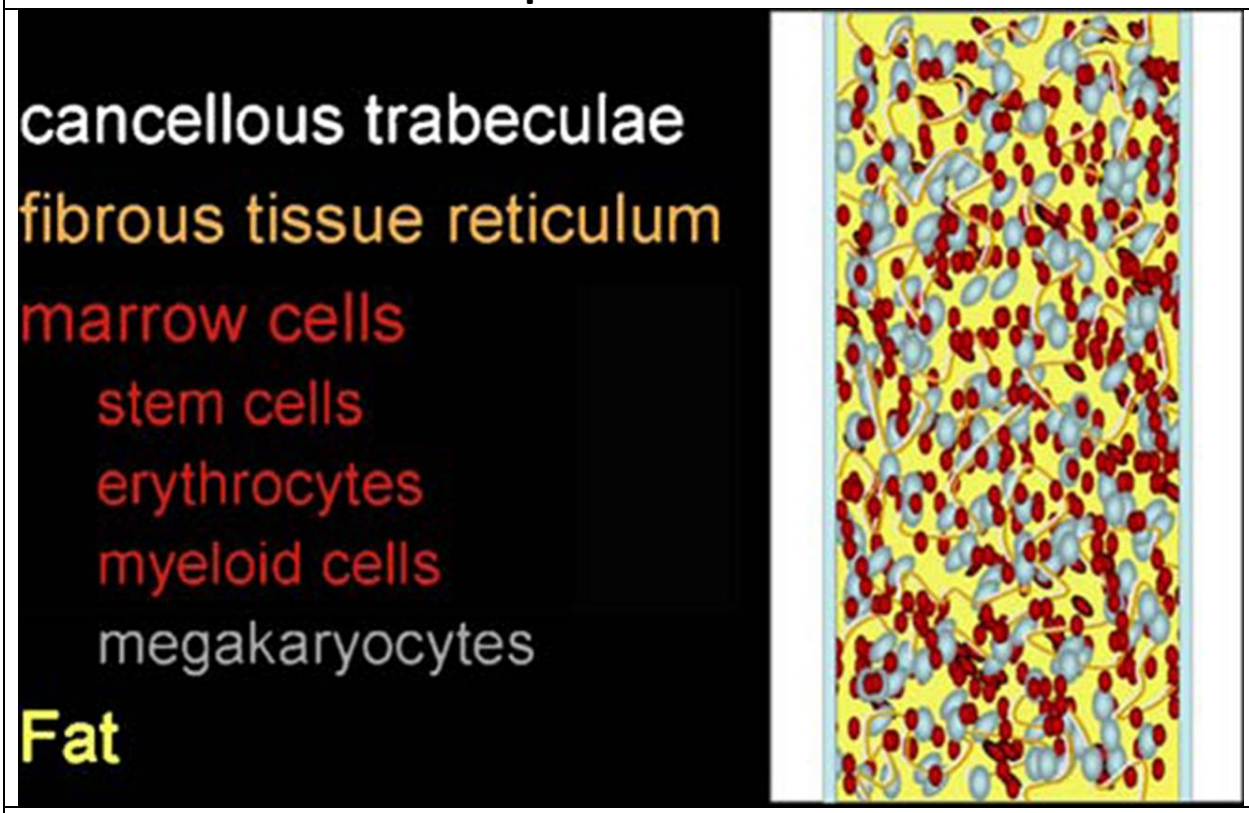
one must first know the

Normal

Normal Bone Marrow

- Bone marrow is one of the largest organs in the body after the osseous skeleton, skin, and body fat, and is mainly composed of Fat and Water

❖ 4 Basic Marrow Components:



❖ Red Marrow vs. Yellow Marrow:

	Red bone marrow	Yellow bone marrow
Water	35%-40%	15%
Fat	40%-45%	80%
Protein	15%	5%

❖MRI appearance:

Fatty BM:

- T1: High SI
- T2: intermediate - high SI
- STIR: Loss of high signal
- +C: No enhancement

Red BM:

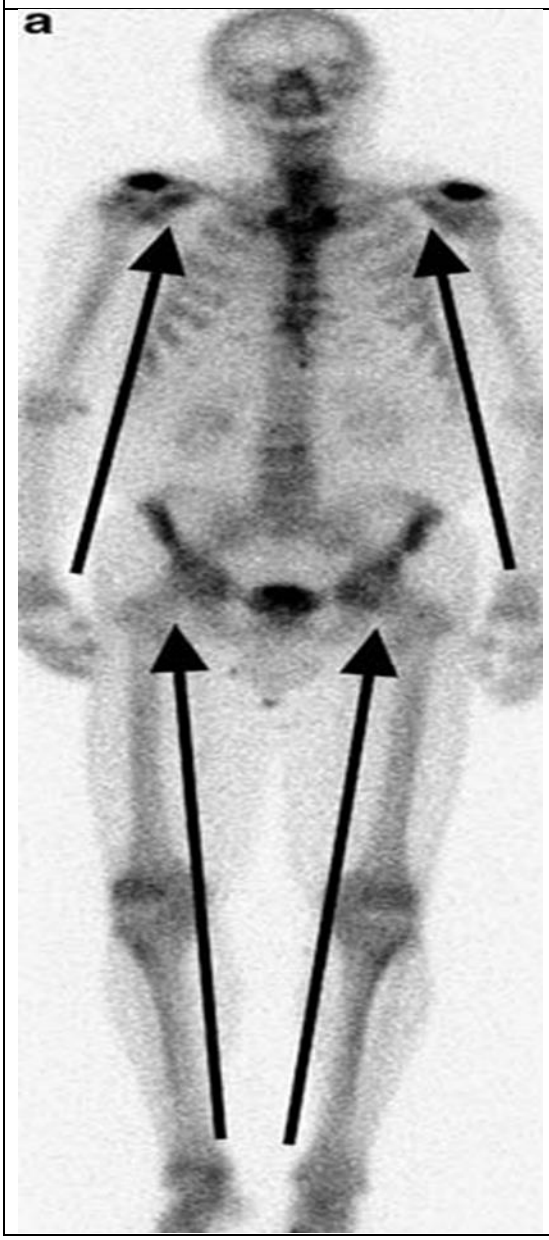
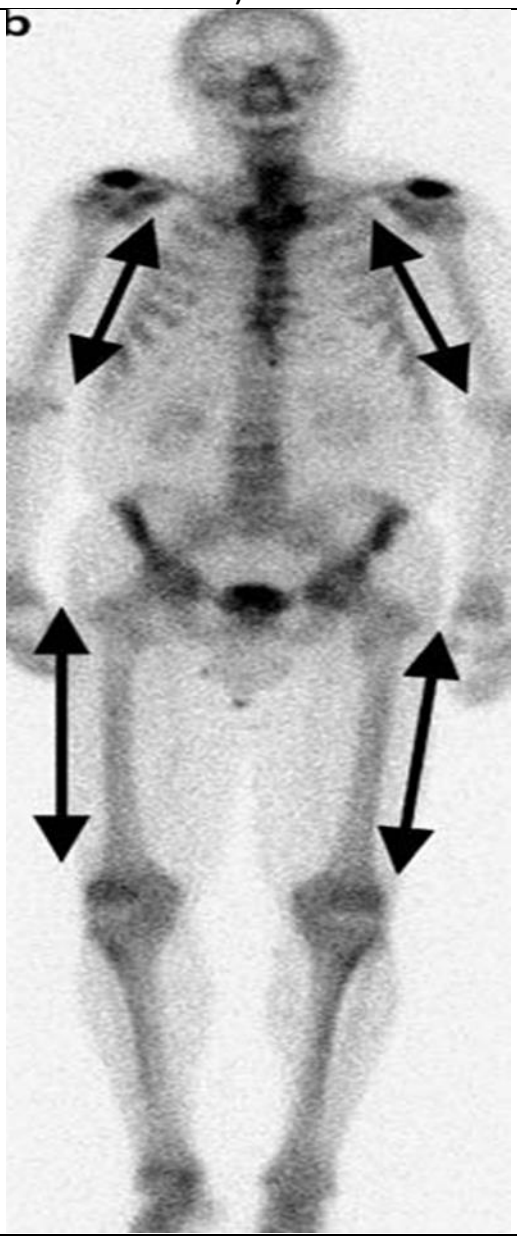
- T1 &T2: Intermediate signal
- hypointense to fat
- Iso or hyperintense to muscles or disc on T1 & STIR WI
- +C: Minimal to mild enhancement

Bone Tumors:

- low signal against a background of surrounding fatty marrow.
- T1: hypointense to muscles or disc on T1 WI
- STIR: hyperintense to muscles on STIR WI
- +C: Moderate to intense enhancement

❖ Age-related conversion of BM

2 superimposed sequences

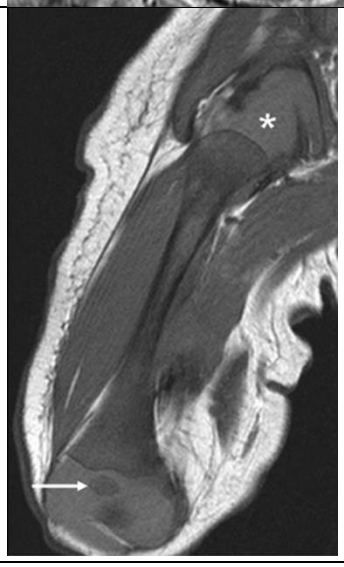
Red marrow converts to yellow marrow from the peripheral to the axial skeleton (arrows).	Red marrow converts to yellow marrow proceeding from diaphysis to metaphysis in long bones (double-headed arrows).
	

In Fetus:

- Thick diaphyseal cortex.
- Small central medullary cavitation.
- The bone cortex rather than the marrow that determines SI
- Low SI on images obtained with all sequences of the long bones throughout the body

In Neonate:

- A larger marrow space becomes evident
- The SI of the shafts of the bone reflects the marrow composition.
- The entire skeleton contains hematopoetic RED marrow:
- T1 WI: isointense to surrounding muscles
- STIR: high SI
- Distal femoral ossification center (arrow) is red marrow.
- Proximal and distal femoral epiphysis (*) is entirely cartilaginous: homogeneous SI.



In the 1st decade:

Marrow conversion of long bones start in
Epiphysis and apophysis

- ⇨ Diaphysis
- ⇨ Distal Metaphysis

Proximal Metaphysis

In the 2nd decade of life:

The long bone marrow becomes predominantly yellow except for residual regions of red marrow in the proximal humeral and femoral metaphyses.

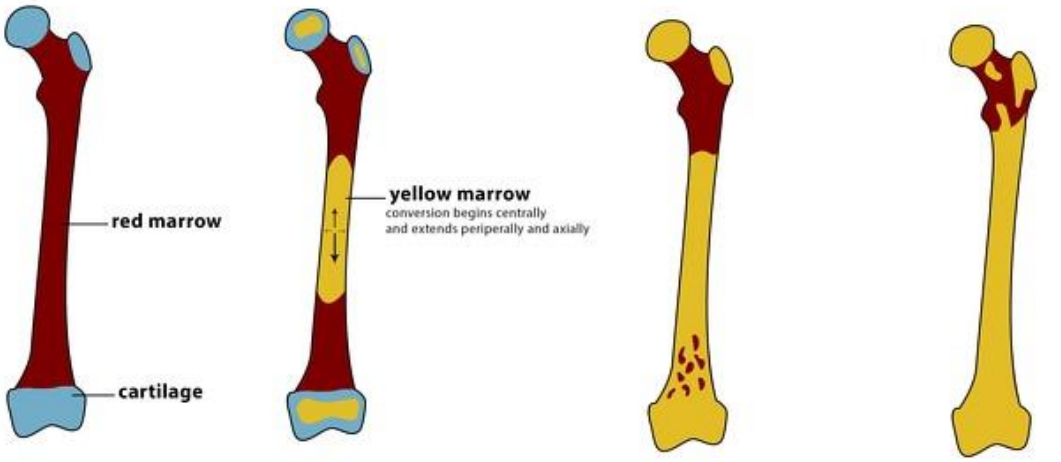
In the 3rd decade of life:

- This conversion is almost complete in the appendicular skeleton by the time of skeletal maturity (25y).

Throughtout Life:

Gradual conversion of red marrow to yellow marrow occurs in the axial skeleton.

Normal bone marrow conversion



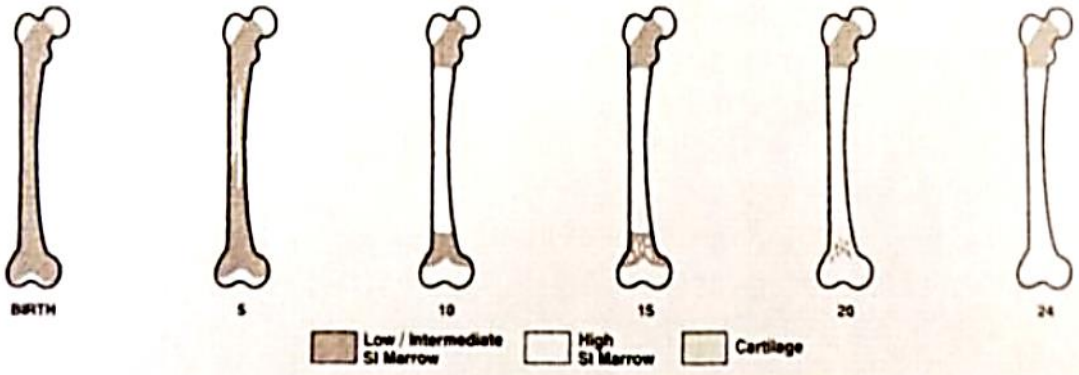
Infant <1 year

Childhood 1-10 years

Adolescent 10-20 years

Adult >25 years

MRI APPEARANCE

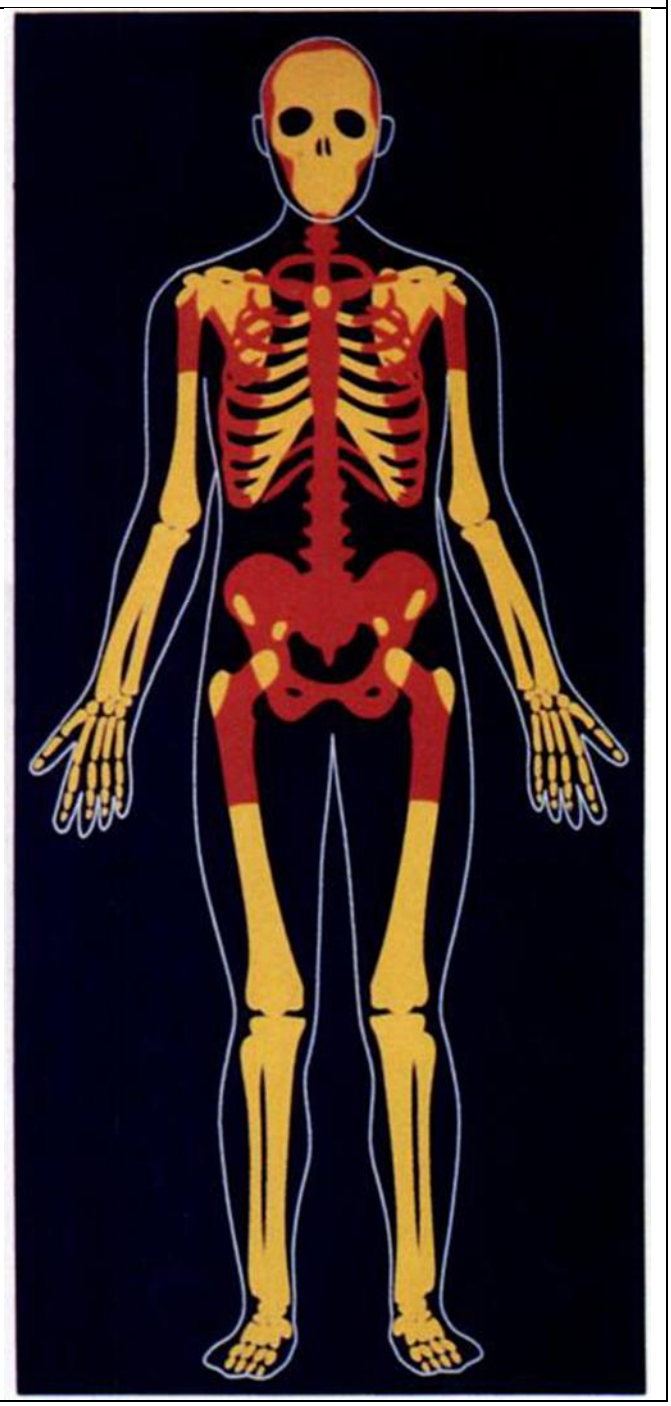


❖ Adult Pattern Of Red And Yellow Marrow Distribution:

Red marrow is situated in

- **Axial Skeleton:**
  - Skull
  - Spine
  - Sternum
  - Clavicle
  - Ribs
  - Pelvis
- **Proximal (metaphyseal) parts of the humerus and femur.**

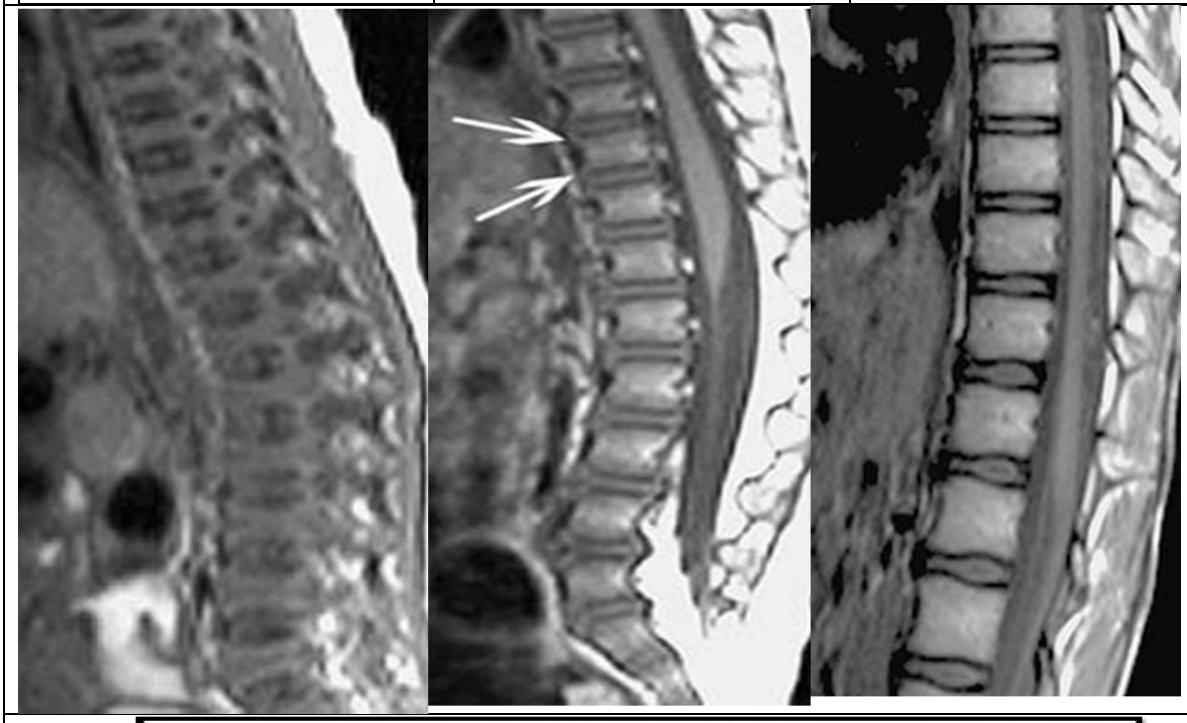
The peripheral skeleton contains fatty (yellow) marrow.

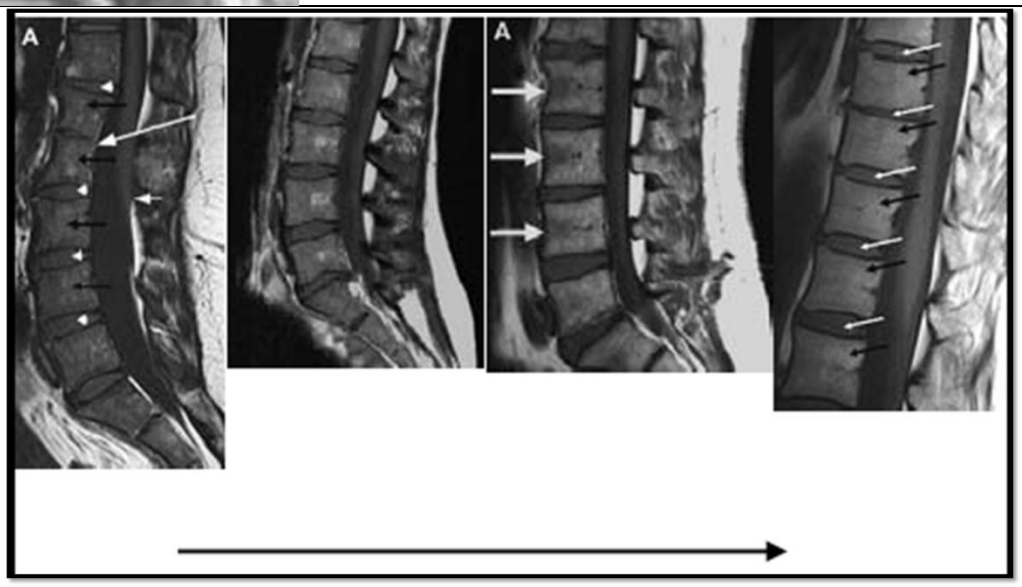


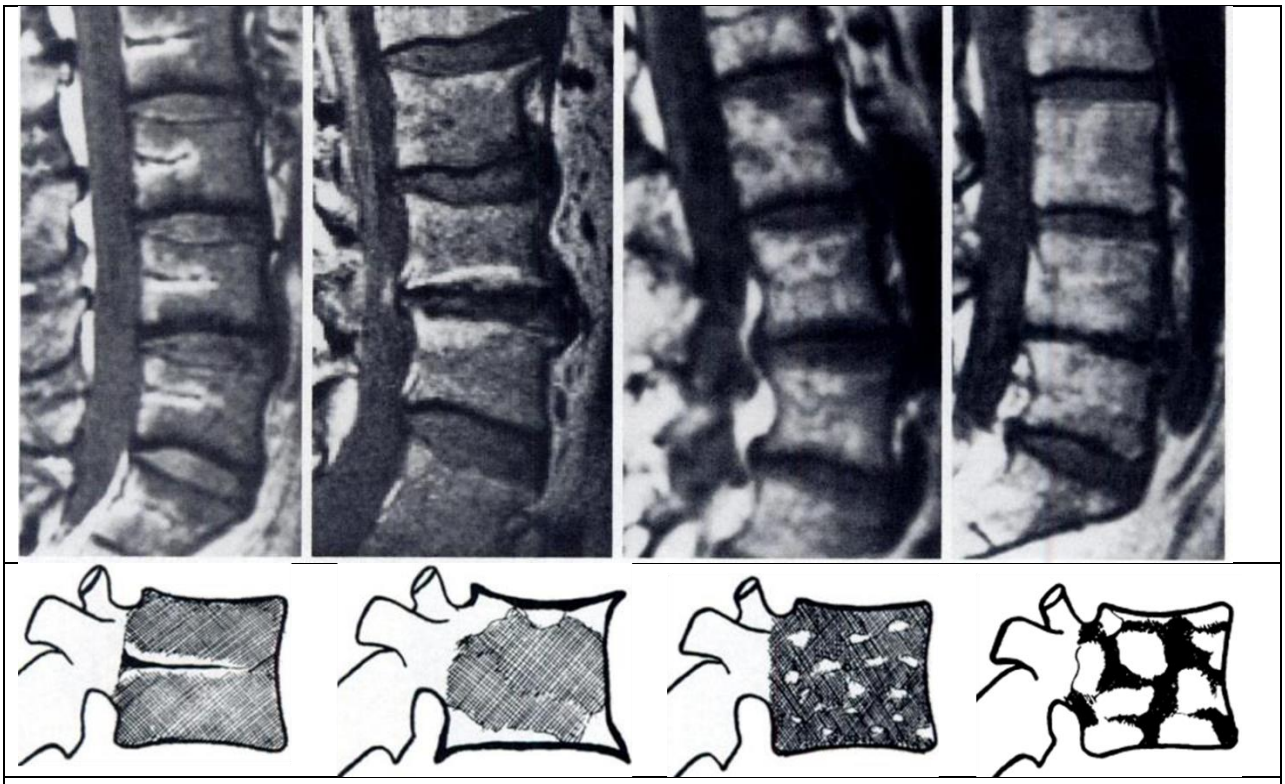
❖Fatty marrow conversion in the Spine

- In the spine, the literature states that on **T1 WI** the SI of the vertebral bodies relative to that of the intervertebral disc is
    - Hypointense before 1 year of age
    - Isointense between 1 and 5 years
    - Hyperintense after 5 years.

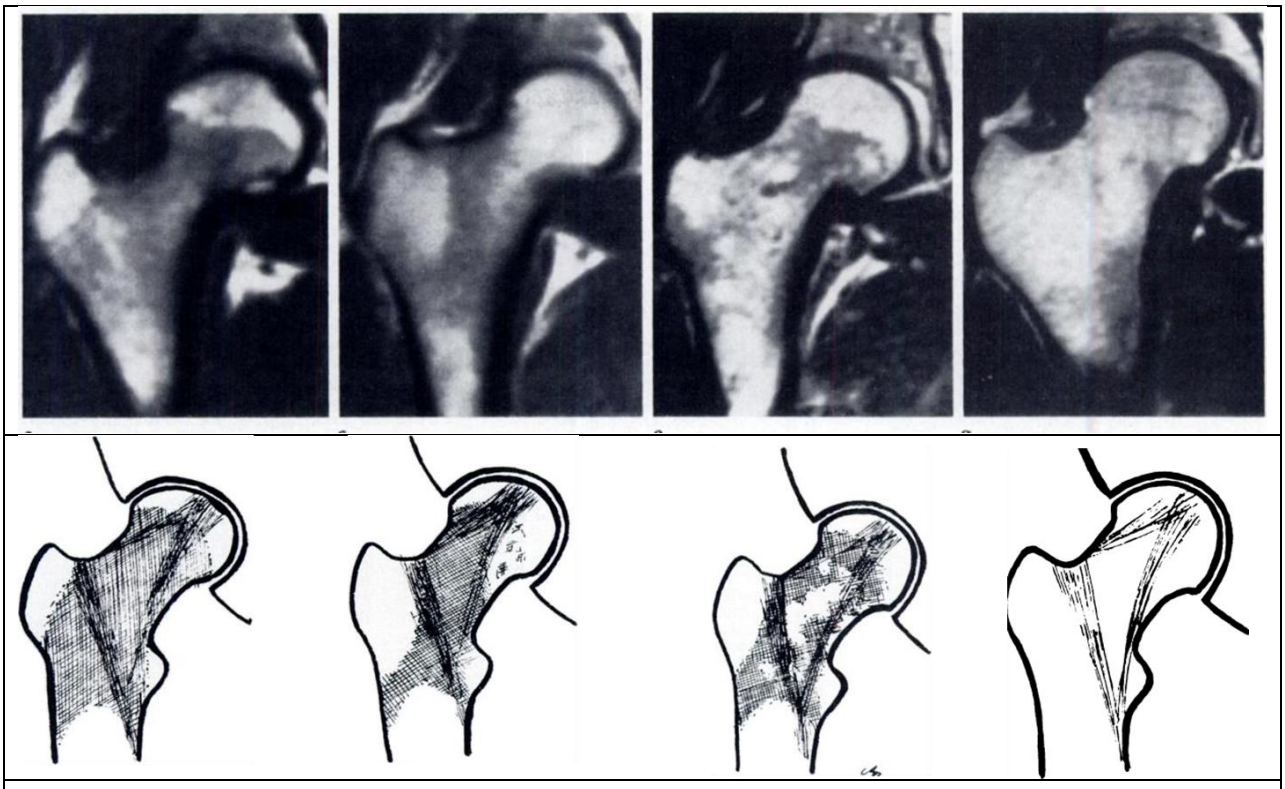
Neonate	1 Y	14 y



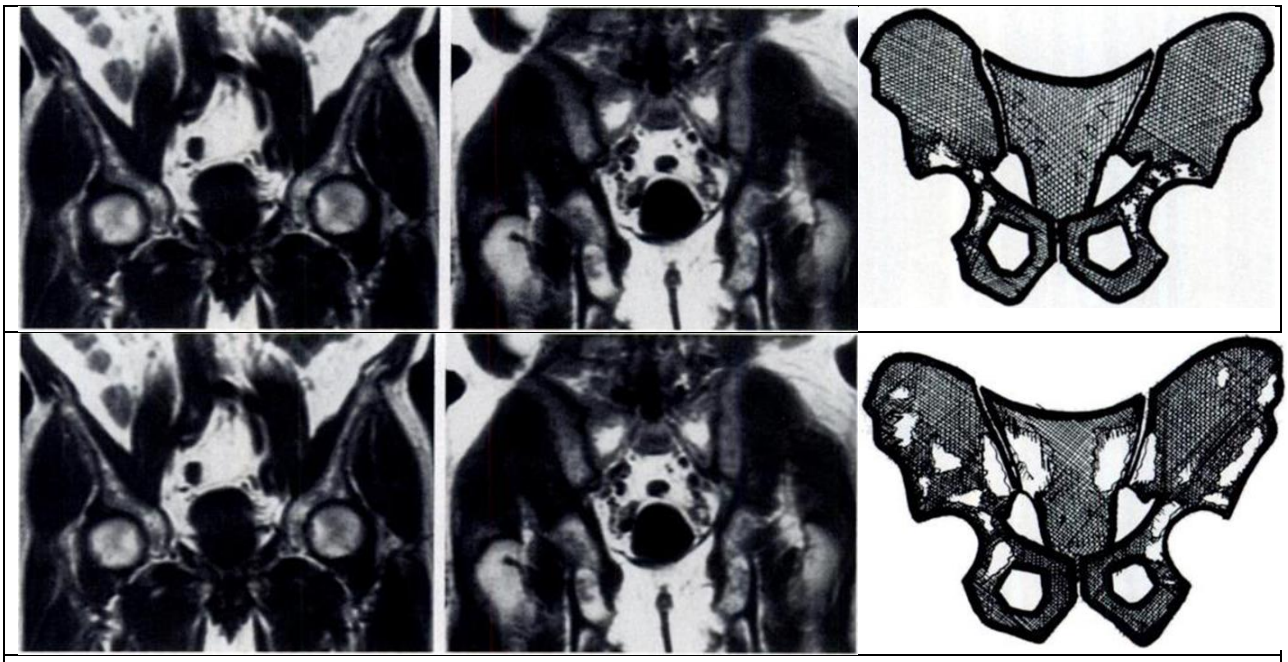




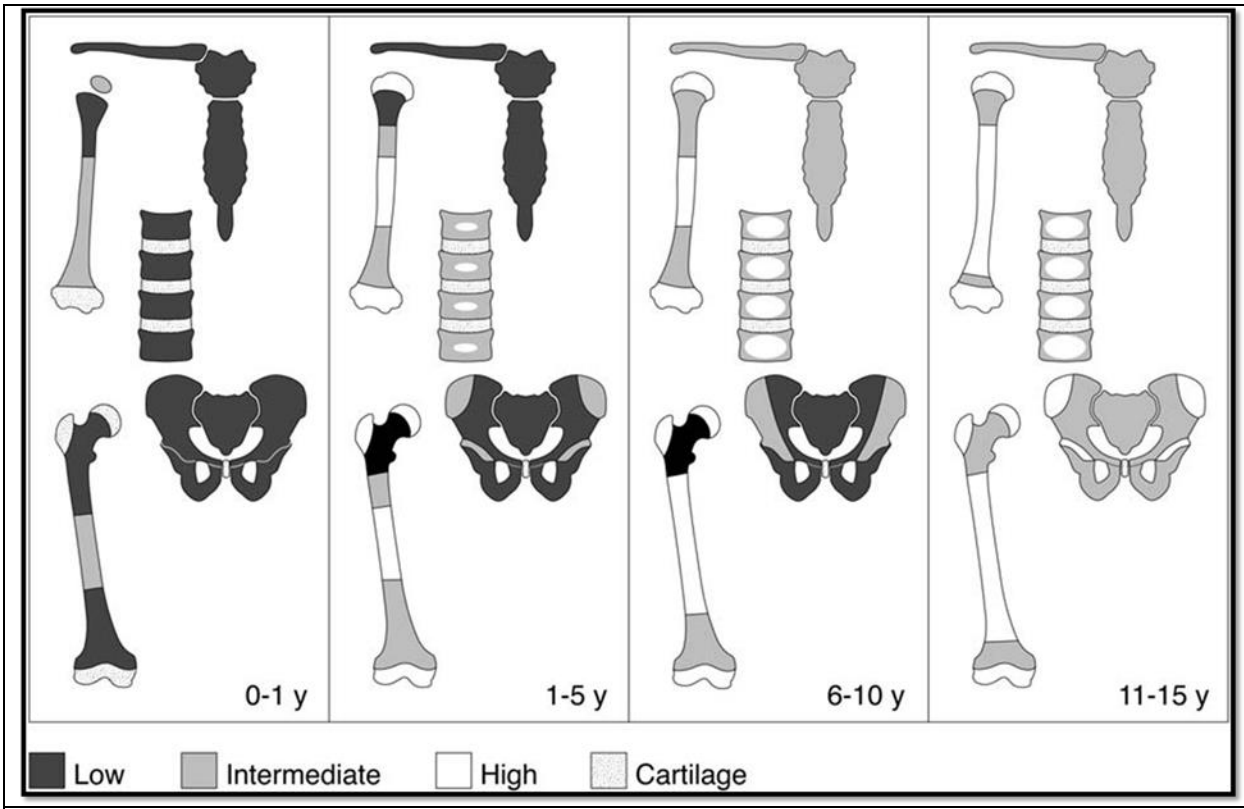
T1 WI and schematics of spinal bone marrow distribution patterns.
(a) Pattern 1. High SI fatty marrow is seen confined to linear areas along the basivertebral vein.
(b) Pattern 2. Bandlike and triangular areas of fatty marrow are located peripherally near the end plates and at the corners of the vertebral body.
(c) Pattern 3a. Multiple small areas of high SI fatty marrow.
(d) Pattern 3b. Multiple, relatively large, fairly well marginated areas of fatty marrow.

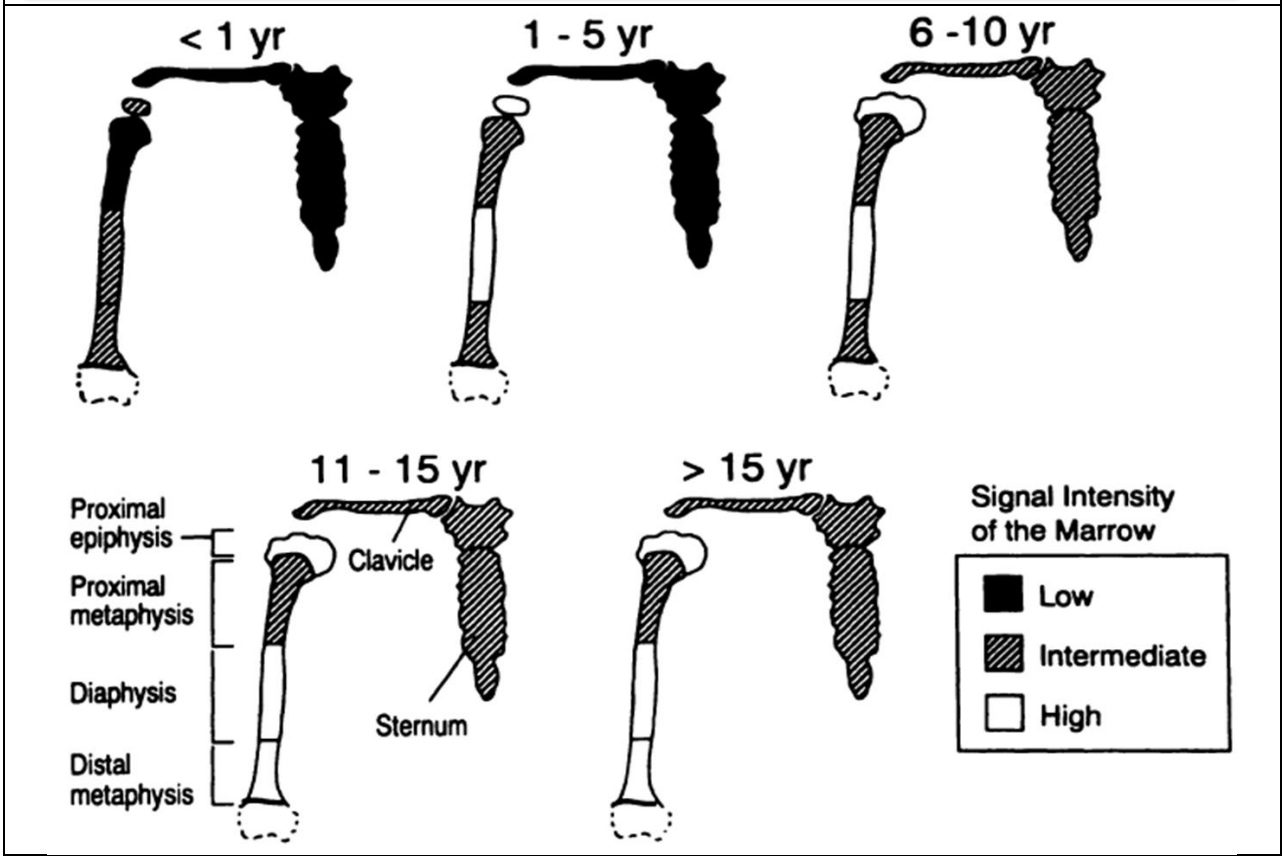


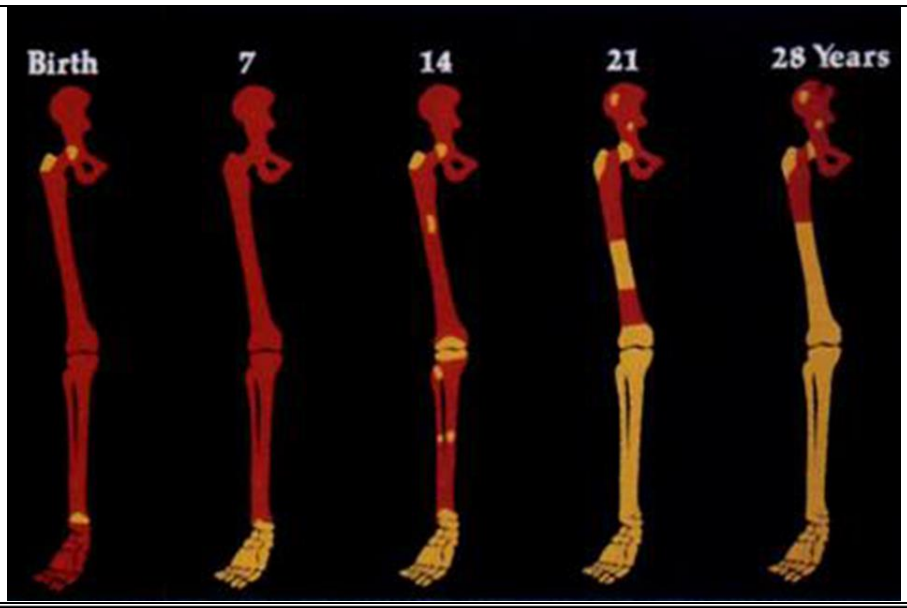
T1 WI and schematics of proximal femur marrow distribution patterns.
(a) Pattern la. High SI fatty marrow is seen confined to the capital femoral epiphysis and greater and lesser trochanters in a 15y
(b) Pattern lb. In addition to the areas seen in pattern la, fatty marrow is seen in a triangular region inferior to the medial portion of the femoral head and in the lateral portion of the intertrochanteric region adjacent to the greater trochanter in a 27-y.
(c) Pattern 2. Many small, sometimes confluent, regions of high-signal-intensity fatty marrow are seen in the intertrochanteric region in addition to the fatty regions of pattern I in a 45-y.
(d) Pattern 3. Relatively uniform, high-signal-intensity fatty marrow occupies essentially all of the proximal femur in a 60-y.

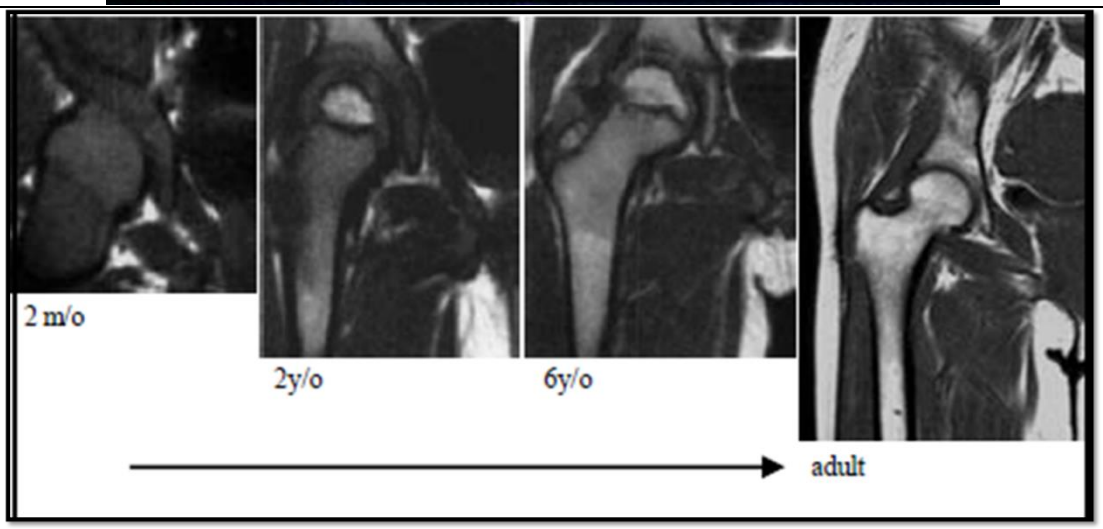


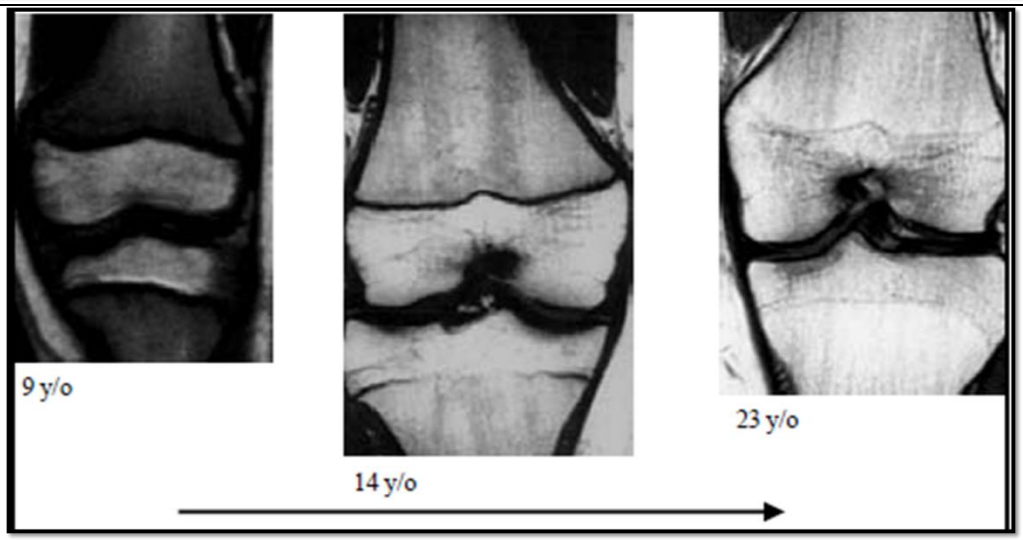
T1 WI MR images and schematics of pelvic marrow distribution patterns.
(a, b) Pattern 1: Small areas of high-signal-intensity fatty marrow are present in the superior medial acetabular region in a 16-year-old boy.
(d, e) Pattern 2: In addition to areas of high signal intensity near the acetabular roof, bright areas in the ilium and near the sacroiliac joints are seen in a 32- year-old woman.


0-1 y
1-5 y
6-10 y
11-15 y
Low
Intermediate
High
Cartilage


< 1 yr
1 - 5 yr
6 -10 yr
11 - 15 yr
> 15 yr
Proximal epiphysis
Proximal metaphysis
Diaphysis
Distal metaphysis
Clavicle
Sternum
Signal Intensity of the Marrow
Low
Intermediate
High


Birth
7
14
21
28 Years


2 m/o
2y/o
6y/o
adult

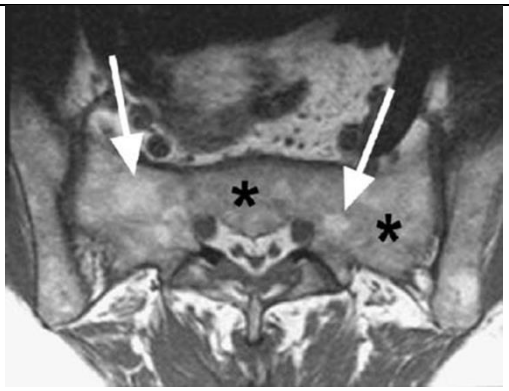

9 y/o
14 y/o
23 y/o

❖ BM Heterogeneity

- The proportions of adipocytes and hematopoietic cells in marrow can change focally or diffusely, resulting in a normal heterogeneity of the marrow on MRI that may be confused with marrow lesions.
- The signal intensity, morphology, and distribution of marrow can help to distinguish such normal variations from marrow lesions.

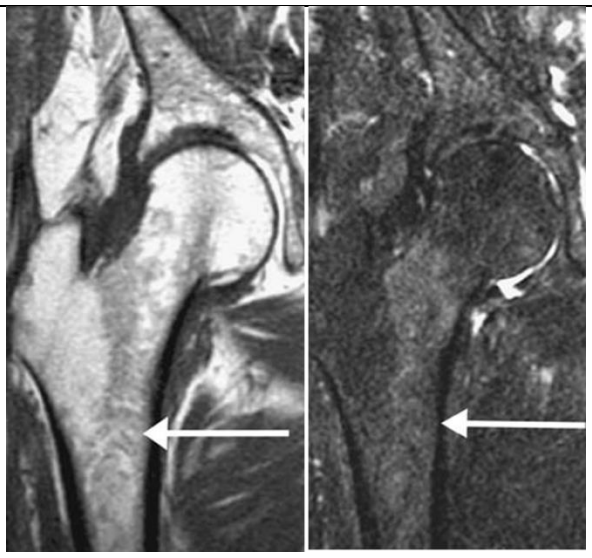
a) Islands of Yellow BM:

- SI similar to that of subcutaneous fat in all sequences.
- Islands of fatty marrow (arrows) are evident within a background of red marrow (asterisks) in sacrum.
- Pelvic marrow is often heterogeneous, reflecting the transitional location of the pelvis between spine (axial, red-marrow-containing) and femurs (peripheral, yellow-marrow-containing)



b) Islands of Red BM:

- T1: lower than that of fat but often higher than that of muscle
- (in contrast to tumor deposits, which are generally isointense or hypointense to muscle)
- STIR: Low SI
- Poorly defined, feathery margins that interdigitate with fatty marrow (metastases tend to be more rounded and sharply defined)



Hematopoietic BM Hyperplasia or Red Marrow Reconversion

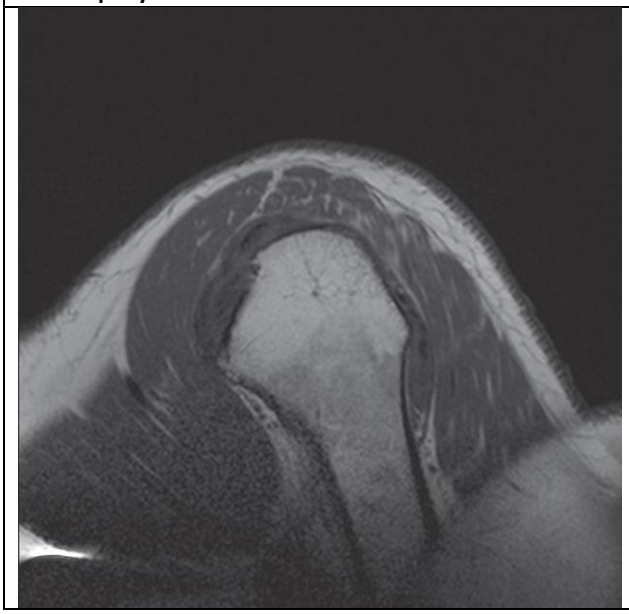
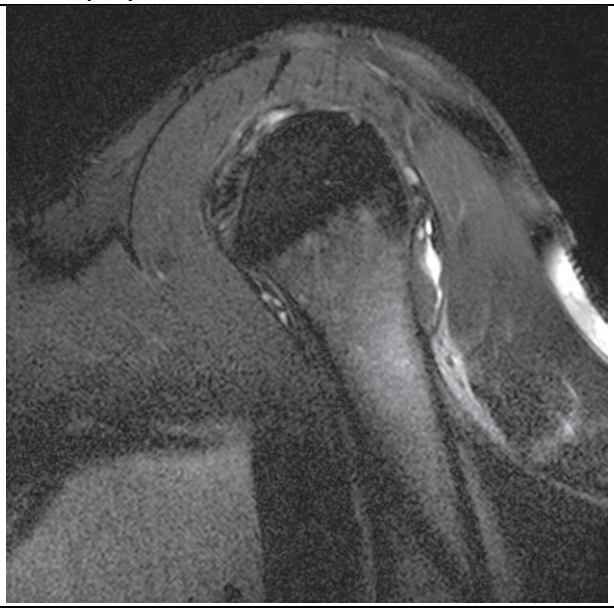
Bone marrow cellularity may be influenced by:

- Smoking
- Menstruation
- High-level athletes (marathon runners)
- Hemolytic anemia
- Hematopoetic growth factor during chemotherapy
- Enzyme therapy e.g. in Gaucher disease
- Endurance activities.

- The reconversion process proceeds in the exact reverse sequence from that of the initial conversion: namely,
- From the central to the peripheral skeleton:
  - The vertebral bodies are the first affected site.
- In the long bones:
  - Start in Proximal metaphyses
  - ⇨ Distal metaphyses
  - ⇨ Diaphyses.
  - ⇨ Epiphyses are the last site to reconvert

Imaging findings:

- T1 WI: Patchy / Diffuse ↓ SI of BM isointense or slightly hyperintense to surrounding muscles.
- STIR: Patchy / Diffuse ↑ SI of BM approximates that of muscle and is less than that of CSF due to higher water content of hematopoietic marrow.

Patchy red marrow reconversion in 45 years old smoking female	
T1: Patchy low signal in distal metaphysis of femur	PD FS: Patchy high signal in distal metaphysis of femur
T1: Patchy low signal in proximal metaphysis of humerus	STIR: Patchy high signal in proximal metaphysis of humerus
	

Osteoporosis

Osteoporosis

- Osteoporosis is a disorder characterized by
- ↓ Bone density (↓ Quantity)
- Increased bone fragility and susceptibility to fracture.
- It is the most common metabolic bone disorder.

A- Primary Osteoporosis:

Type I: Postmenopausal
Type II: Senile
Type III: Juvenile

B- Secondary Osteoporosis:

Endocrine disorders:
Hypogomadism
Acromegaly
Cushing
Hyperthyroidism
Hyperparathyroidism

Nutritional
Malabsortion syndrome
Alcholism
Scurvey

Hereditary metabolic or collagen disorder:
Osteogenesis imperfecta
Marfan syndrome
Ehlers-Danlos syndrome
Hypophosphatsia
Homocystinuria
Alkaptonuria
Menkes' disease
Wilson's disease

Drugs:
Heparin
Exogenous steroids

C- Regional Osteoporosis

which affects only part of the skeleton

- Immobilization or disuse
- Reflex sympathetic dystrophy syndrome
- Transient osteoporosis of large joints

Role of Diagnostic Imaging

- To identify the presence of osteoporosis.
- To quantify bone mass with use of:
    - Semiquantitative
        - Conventional radiography
    - Quantitative (densitometry) methods:
        - Dual-energy x-ray absorptiometry (DXA)
        - Quantitative CT
        - New MRI Techniques

1) Conventional Radiography

- Conventional radiography is a projectional imaging modality with a spatial resolution of up to 40m.
- It provides a good tissue contrast, is widely available and has the potential to reflect bone micro-architecture
- The main radiographic features of generalized osteoporosis are:
    - Increased radiolucency
    - Trabecular Resorption
    - Cortical Thinning

i) Tubular Bones

Cortical Thinning

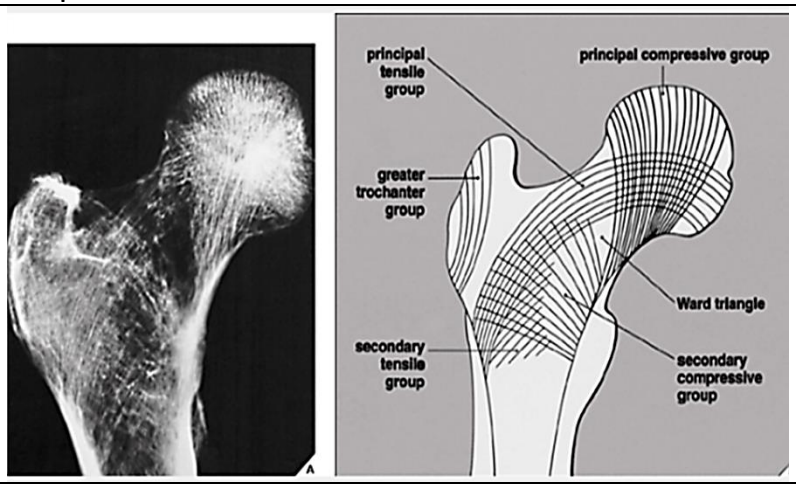
- is the result of osseous resorption in the cortex.
- Endosteal (inner surface of cortex) => endosteal scalloping
- Periosteal (outer surfaces of cortex) => subperiosteal resorption
- Intracortical (within the cortex) => cortical striations / tunneling

Trabecular resorption:

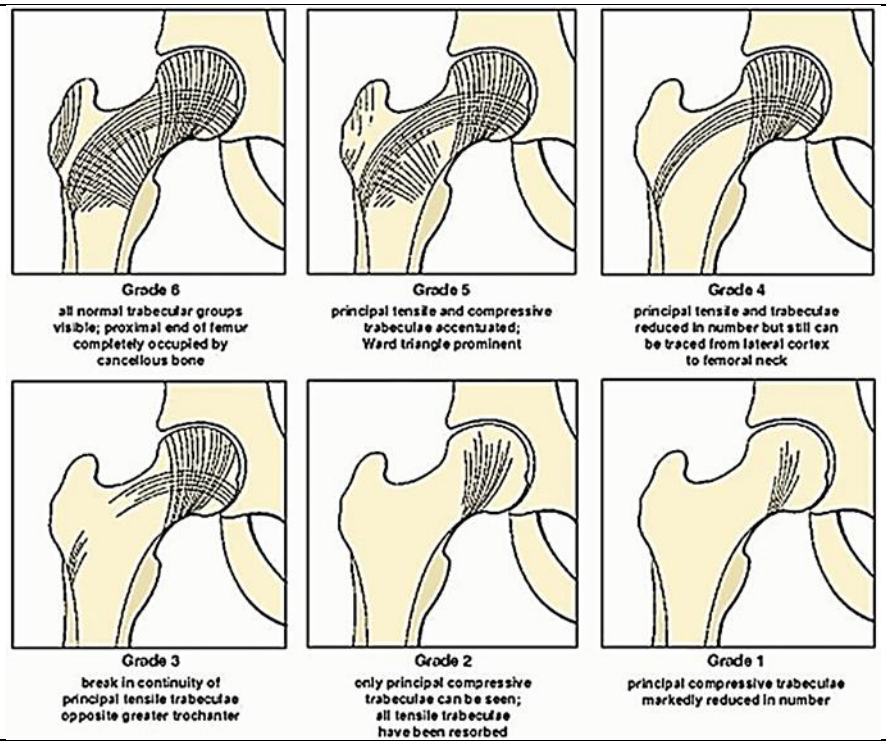
- Subchondral => linear / spotty translucency
- Metaphyseal => Bandlike translucency
- Diffuse => homogenous / spotty translucency

ii) Femoral Neck:

- Rarefaction of 2ry trabeculae.
- Accentuation of the principal compressive and principle tensile trabeculae.
- Prominent Ward area = which manifests on radiographs as enclosure of the proximal femur by the principal and secondary compressive trabeculae and the tensile trabeculae)
- Loss of the tensile trabeculae.
- Loss of the compressive trabeculae



❖Singh's Index


Grade 6
all normal trabecular groups visible; proximal end of femur completely occupied by cancellous bone
Grade 5
principal tensile and compressive trabeculae accentuated; Ward triangle prominent
Grade 4
principal tensile and trabeculae reduced in number but still can be traced from lateral cortex to femoral neck
Grade 3
break in continuity of principal tensile trabeculae opposite greater trochanter
Grade 2
only principal compressive trabeculae can be seen; all tensile trabeculae have been resorbed
Grade 1
principal compressive trabeculae markedly reduced in number

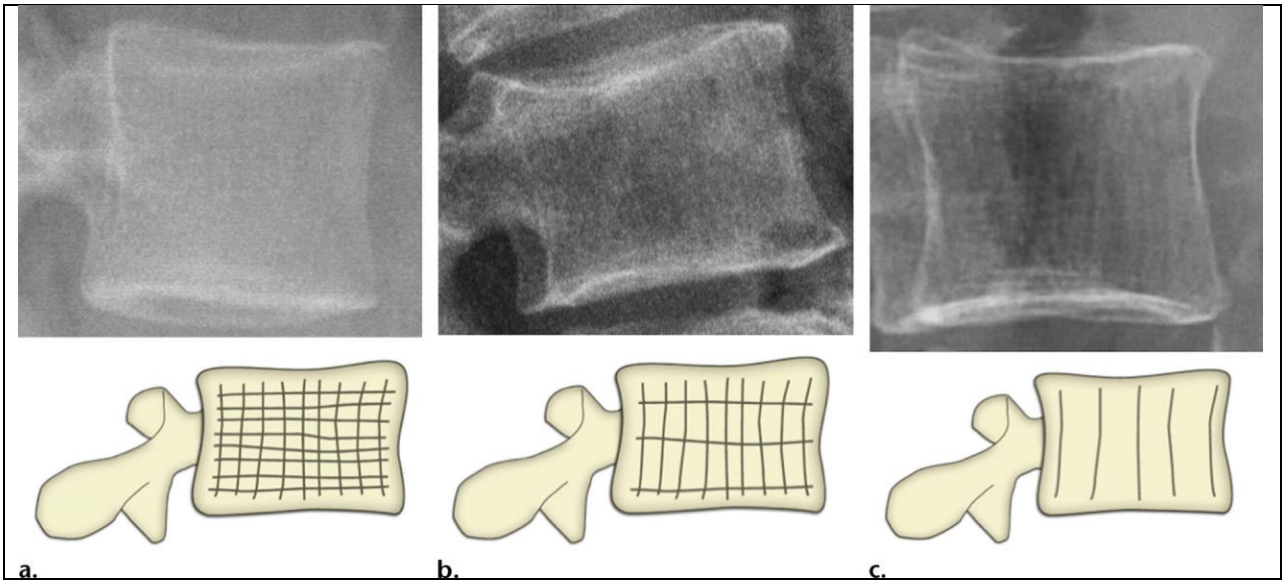
iii) Vertebrae

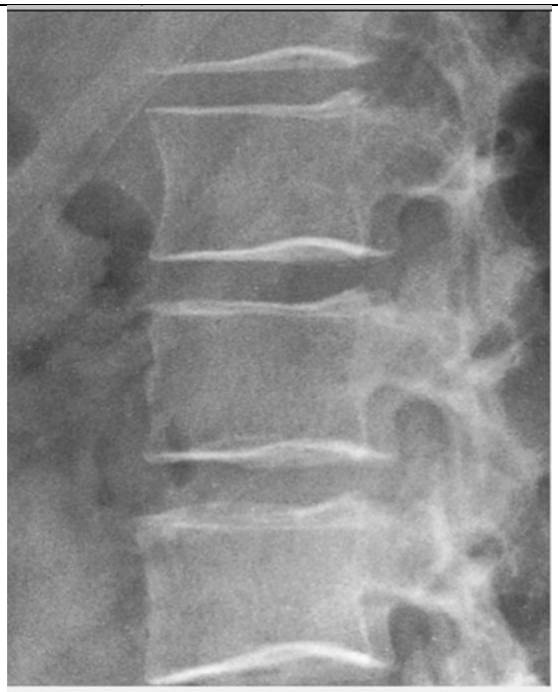
Change in density:

- Rarefaction of the horizontal (secondary) trabeculae accompanied by relative accentuation of the vertical (primary) trabeculae.
- Rarefaction of the vertical trabecular+ thinning of the cortex usually remains sharp and clear in osteoporosis => Empty box / picture frame.

Change in shape:

- Wedge fractures when the anterior height is reduced in relation to the posterior height > 3mm
- Endplate fractures (Biconcave = Codfish) when the midheight is reduced in relation to the posterior height,
- Crush fractures (Vertebra plana) when all the heights of a vertebra are reduced in relation to those of adjacent vertebrae.



Empty box" appearance.	Codfish Vertebrae
overall increased radiolucency, A well-demarcated cortical rim, verticalization of the trabeculae	Biconcavity of the body, which exhibits a "fish mouth" appearance
	

iv) Hand:

- Radiologic imaging of the hand is a fundamental step in evaluating grade and type of osteoporosis.
- The metacarpal bones (usually the second, third, and fourth) are investigated, with spongioid and cortical compartments being evaluated separately.
- The corticomedullar index, which is based on the evaluation of the cortical thickness at the second metacarpal bone, represents a good semiquantitative measure for grading osteoporosis at this site.
- Metacarpal radiogrammetry and morphometry are the longest established quantitative methods for assessing the skeleton, having been available for more than 70 years.

2) Digital X-ray Radiogrammetry [DXR])

- This technique provides an estimate of BMD at DXR made on the basis of basic geometric measurements, which are calculated automatically. The metacarpal bones are identified on the digitized posteroanterior hand radiograph using the computer vision algorithm of active shape models.

- Automatic segmentation of the cortical and medullary regions of the midshafts of the second, third, and fourth metacarpal bones is performed, providing the average cortical thickness and average bone width over the prescribed bone region of interest (ROI)
- The relationship between the attenuation of the skeleton and its BMD is determined by comparing the attenuation values obtained with standard values in phantoms of known density (higher attenuation indicates higher density).
- DXR has been shown to have
    - high reproducibility;
    - the capacity to help predict future fracture;
    - the potential to provide a simple, widely available, and inexpensive method of assessing patients who are at risk for osteopenia or osteoporosis and might appropriately be referred for central DXA

3) Dual-Energy X-Ray Absorptiometry (DEXA)

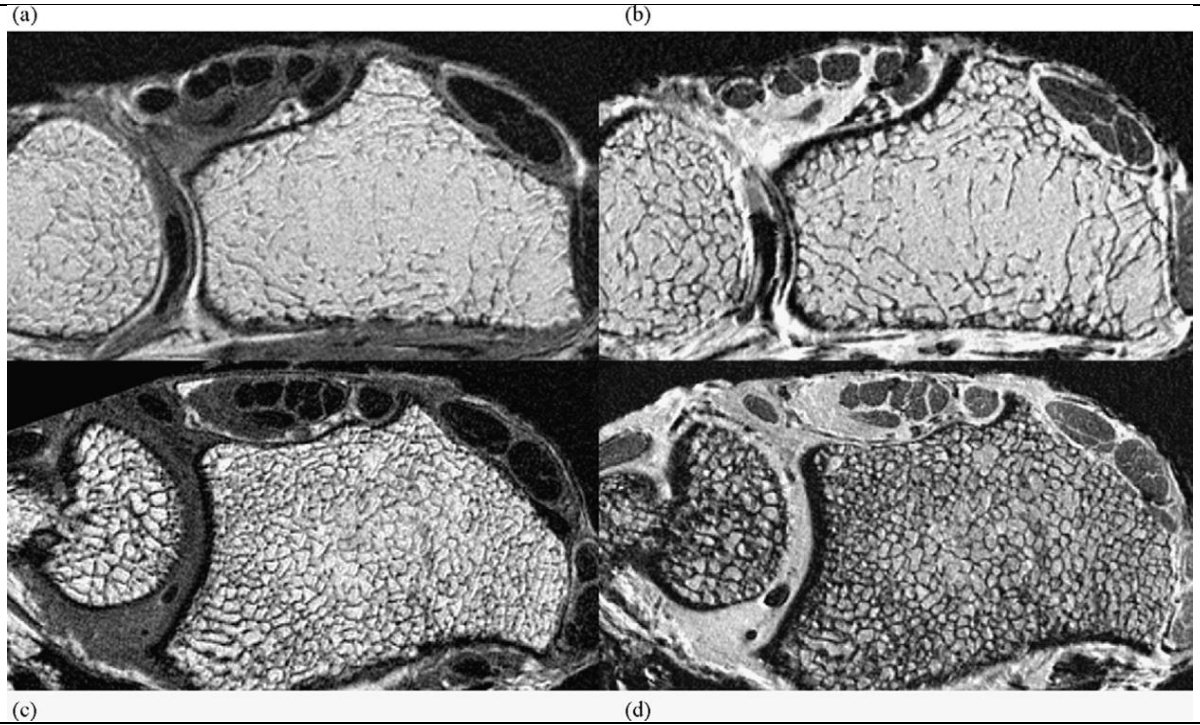
- The advantages of DXA include
    - Low radiation dose,
    - Low cost, ease of use,
    - Rapidity of measurement.
- However, DXA, a two-dimensional technique, does have inherent limitations. It cannot help distinguish between cortical and trabecular bone and cannot help discriminate between changes due to bone geometry (eg, increases in the third dimension) and those due entirely to increased bone density (within a fixed volume of bone).

4) Quantitative CT:

- Lateral chest radiographs and CT (sagittal reformations from 3D volume MDCT) are performed in many elderly patients and can be used to identify vertebral fractures.
- An estimate of BMD can also be obtained from contrast enhanced CT scans

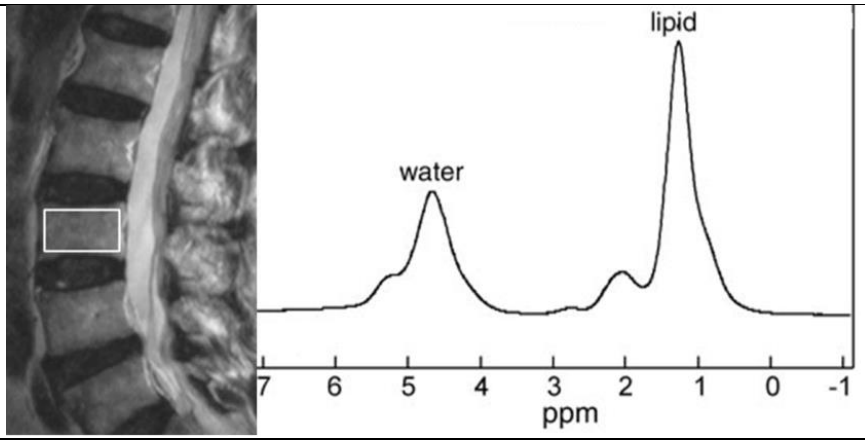
5) High Resolution Gradient Echo MRI:

- When imaging trabecular bone with MR, one must be aware that trabecular bone itself is not visualized.
- A trabecula appears as a signal void, surrounded by high-intensity fatty bone marrow.



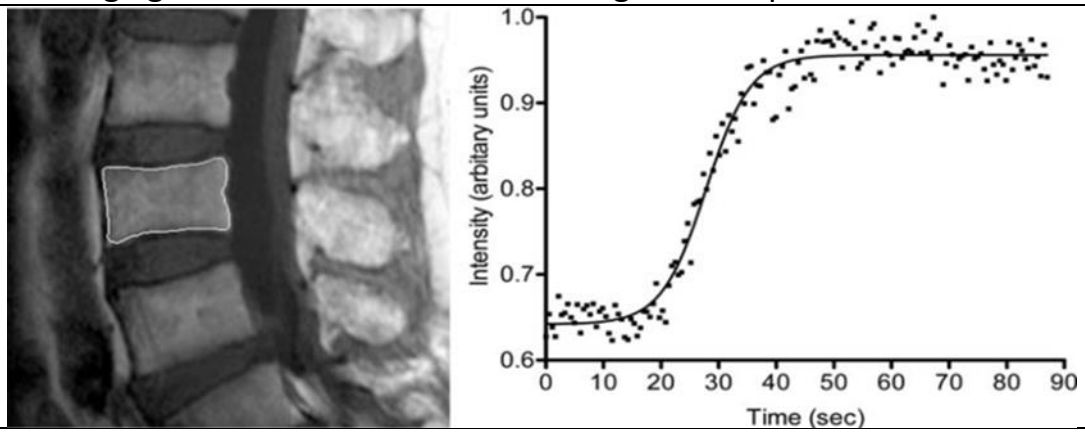
6) MRS:

- Vertebral marrow fat content increases with age, although it is unclear whether this increase is due to an increase in adipocyte size or adipocyte number
- Hydrogen 1 (1H) MR spectroscopy– based studies have revealed an age-dependent linear increase in vertebral marrow fat content



7) Dynamic contrast enhanced MRI:

- Dynamic contrast enhanced MR imaging is a reliable method of estimating bone marrow perfusion
- Individuals older than 40 or 50 years have, on average, decreased vertebral marrow perfusion compared with the perfusion in individuals younger than 40 or 50 years.
- Increasing age is associated with decreasing marrow perfusion.



Vitamin Deficiency Bone Disease

A- Rickets

- Essential bone abnormality is faulty mineralization (calcification) of the bone matrix
- If adequate amounts of calcium and phosphorus are not available, proper calcification of osteoid tissue cannot occur.
- Low serum values of calcium and phosphorus + increased alkaline phosphatase is increased.

Aetiology:

↓ Vitamin D Intake

- Nutritional Deficiency
- Insufficient sunlight

↓ Vitamin D Absorption:

- Gastric surgery
- Gastric disorders (obstruction)
- Intestinal surgery (bypass)
- Intestinal disorders (sprue)
- Biliary diseases
- Pancreatic insufficiency
- Rapid intestinal transit

↓ Vitamin D Conversion:

- Renal Disorders
- Renal tubular disorders:
- Proximal tubular lesions (failure of absorption of inorganic phosphate, glucose, amino acids)
- Distal tubular lesions (renal tubular acidosis)
- Combined proximal and distal tubular lesions
- Renal osteodystrophy

Radiographic Findings:

Skull:

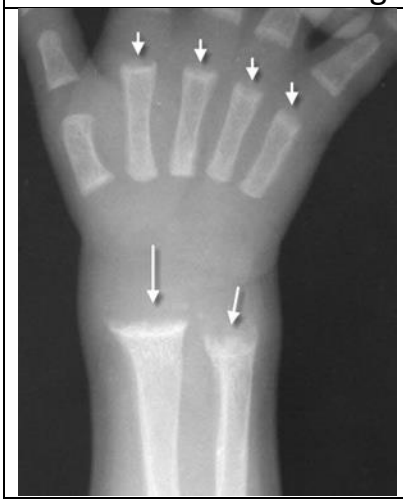
- Delayed closure of fontanelle
- Widened sutures
- Frontal bossing
- Occipital flattening
- Box shaped skull
- Basilar invagination

Long Bones => Active Rickets:

- Metaphysis and the epiphysis (the regions where growth is most active):
  - **Distal ends of the radius, ulna, and femur**
  - **Proximal ends of the tibia and fibula**
- Deficient mineralization in the provisional zone of calcification
- Epiphysis => Poorly mineralized epiphyseal centers with delayed appearance of ossification centers
- Epiphyseal plate => Irregular widening (increased osteoid)
- Metaphysis => Cupping and fraying
- Diaphysis => Bowing deformity and fractures
- Periosteal reaction may be present

Long Bones => Active Rickets:

- Widened growth plate
- Mild metaphyseal cupping
- Sclerotic bands along metaphyseal side of growth plate,



Bowing deformity **Knock Knee**	**<u>Chest</u>** **Rosary beads** **Enlarged osteochondral junctions** **Pigeon chest**

B- Vitamin D-Resistant Rickets

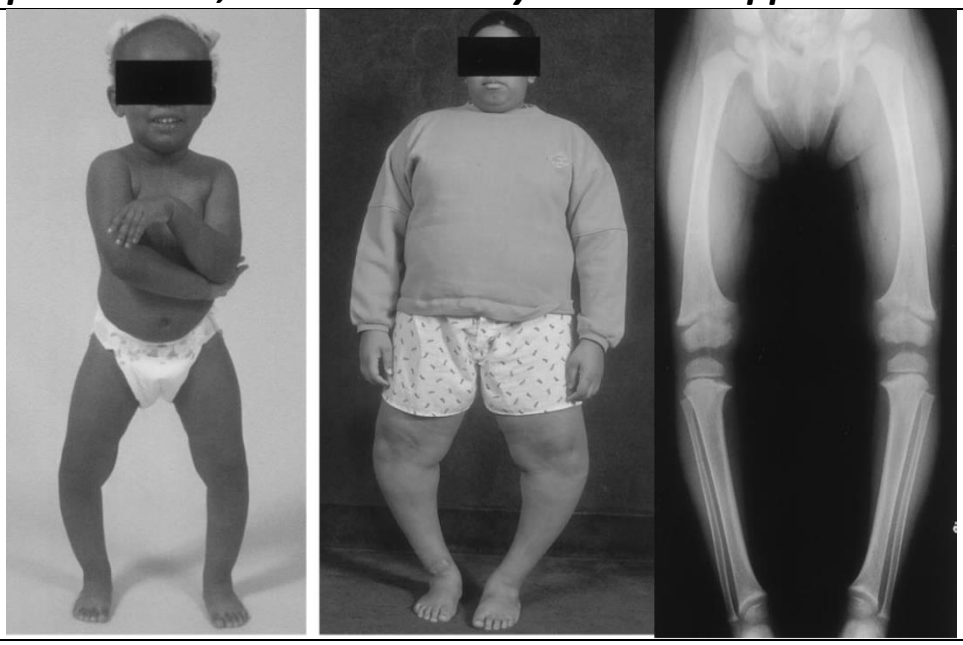
- **Older children > 30 months of age**
- **4 distinct types:-**

1) <u>Classic Vitamin D-Resistant (or hypophosphatemic)</u>
<u>= Familial Vitamin D-Resistant Rickets:</u>

- A congenital disorder that is transmitted as a sex-linked dominant trait.
  ↓P , normal calcium.
- Patients are short, stocky, and bowlegged.
- Ectopic calcifications and ossifications in the axial and the appendicular skeleton, along with occasional sclerotic changes, are among the identifying radiographic findings.

2) **<u>Vitamin D-resistant rickets with glycosuria</u>** is characterized by an abnormal resorptive mechanism for glucose and inorganic phosphate.
3) **<u>Fanconi syndrome</u>** is characterized by a defect in the proximal renal tubules and deficient resorption of phosphate, glucose, and several amino acids.
4) **<u>Acquired hypophosphatemic syndrome</u>** manifests in late adolescence or early adulthood; it is probably of toxic etiology.

- ***The radiographic findings in all 4 types of vitamin D-resistant rickets are similar to those in infantile rickets.***
- ***Bowing of the legs and shortening of the long bones, however, are more pronounced, and occasionally the bones appear sclerotic.***



C- Osteomalacia

- Abnormal mineralization of bone in adults
- Results from the same pathomechanism as rickets
- Occurs only after bone growth has ceased
- It is most often caused by faulty absorption of vitamin D from GIT secondary to malabsorption syndrome.
- Result from dysfunction of the proximal renal tubules, resulting in so-called renal osteomalacia.
- C/P bone pain and muscle weakness

Radiographic Findings:

- **Generalized osteopenia**
- **Pseudo-fractures" = Looser zones :-**
  - Multiple, bilateral, and often symmetric radiolucent lines in the cortex perpendicular to the long axis of the bone:
    - **Axillary margins of the scapulae**
    - **Inner margin of the femoral neck**
    - **Proximal dorsal aspect of the ulnae**
    - **Ribs**
    - **Pubic and ischial rami**

Milkman's Syndrome:

- Osteomalacia + many Looser's zones

Looser zone at inner margin of Femoral Neck	**Looser zone at axillary margin of Scapula**

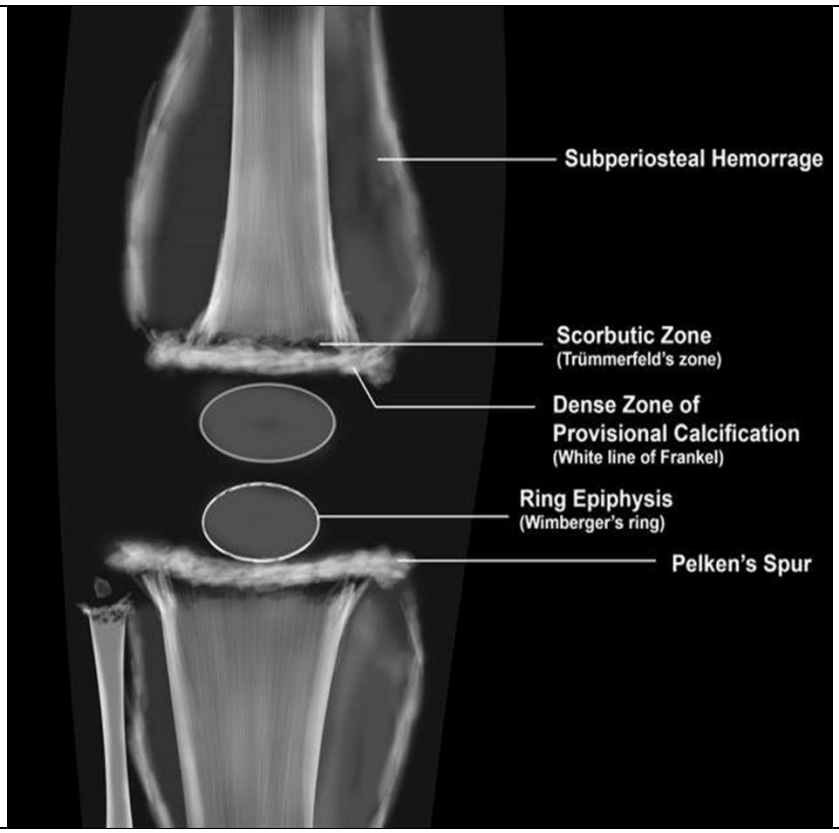
D- Scurvy

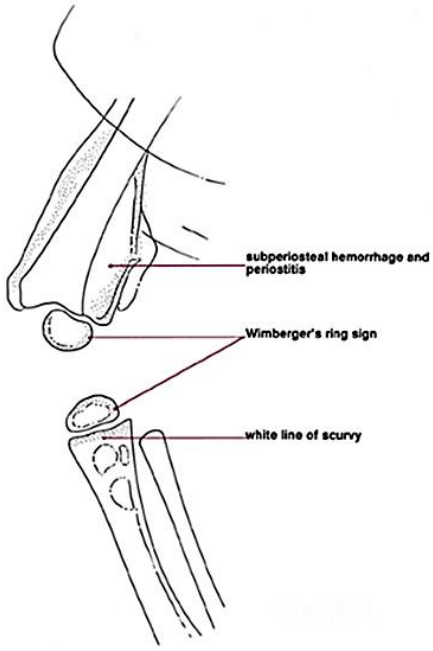
(Barlow Disease Vitamin C Deficiency)

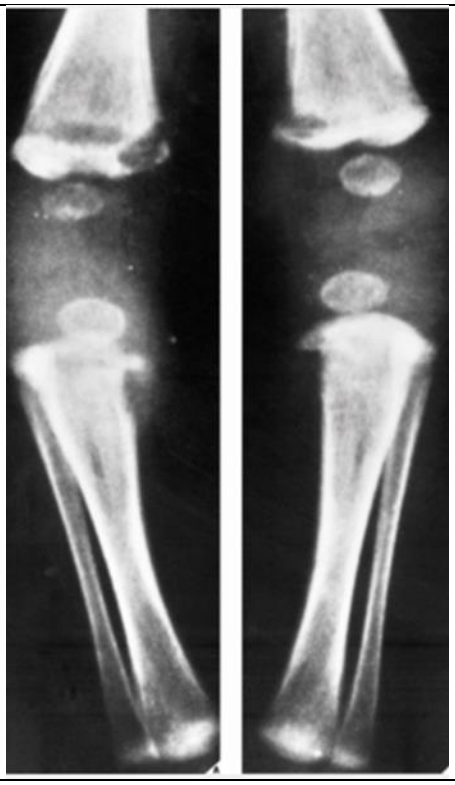
- Deficiency of vitamin C (ascorbic acid) impairs the ability of connective tissue to produce collagen
- Never occurs before 6m of age because maternal stores are transmitted to fetus.

Radiographic findings:

- Generalized osteopenia
- Wimberger ring = Ring epiphysis
- White line of Frankel = Dense metaphyseal line
- Trummerfield zone = Lucent metaphyseal line
- Pelken spur = metaphyseal corner fracture
- Cortical thinning
- Subperosteal hematoma with calcification of elevated periosteum




subperiosteal hemorrhage and periostitis
Wimberger's ring sign
white line of scurvy



Endocrine Bone Disease

A- Hyperparathyriodism (HPTH)

Subtypes

i. **Primary Hyperparathyroidism**
   - Parathyroid Adenoma (~80%)
   - Parathyroid Hyperplasia (10-15%)
   - Parathyroid Carcinoma (1-5%)
   - F:M =3:1
   - 3rd -5th decade

ii. **Secondary Hyperparathyroidism**
   - caused by chronic hypocalcaemia with **renal osteodystrophy** being the most common cause (others include malnutrition, vitamin D deficiency)
   - results in parathyroid hyperplasia

iii. **Tertiary Hyperparathyroidism**
   - Autonomous parathyroid adenoma caused by the chronic overstimulation of hyperplastic glands in renal insufficiency

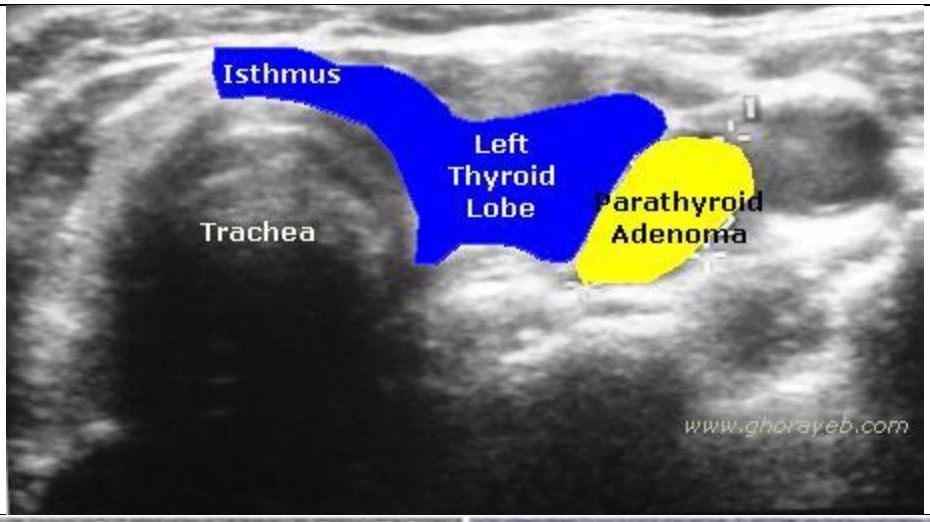
		Primary	Secondary	Tertiary
Serum	Calcium	inc	norm or dec	inc
	Phosphorous	dec	inc	inc
	Alkaline Phosphatase	inc or norm	inc or norm	inc or norm
Urine	Calcium	inc	dec	
	Phosphorous	inc	dec	

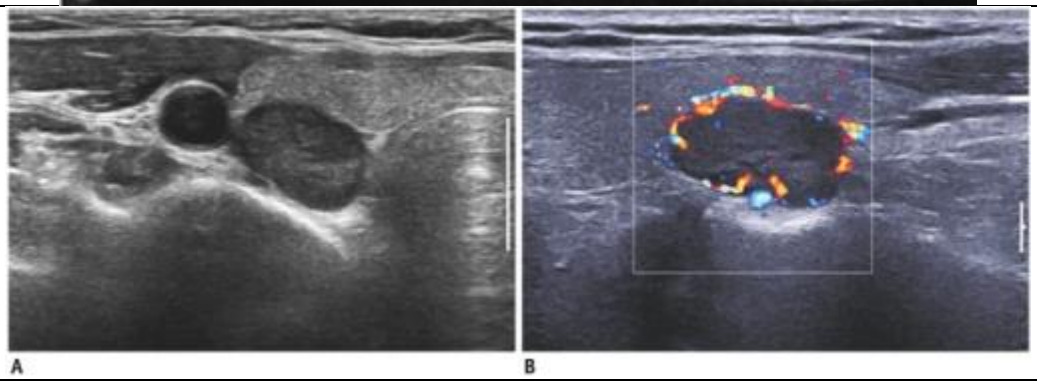
❖ Associations

MEN-type I = 3P (PTH adenoma, Pituitary adenoma, Pancreatic islet tumor)
MEN-type II = PTP (PTH adenoma, Thyroid medullary carcinoma, Pheochromocytoma)

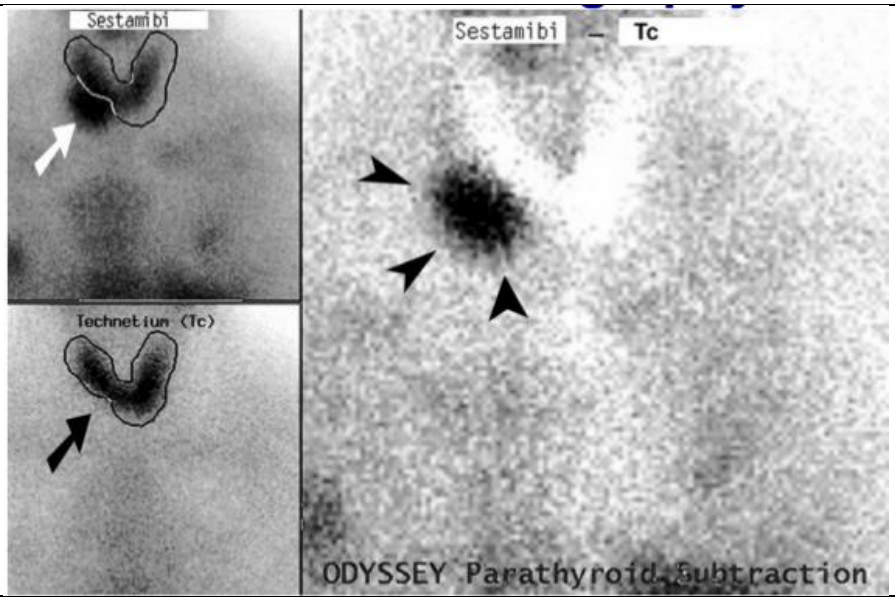
❖Parathyroid Adenoma Imaging

US & Doppler

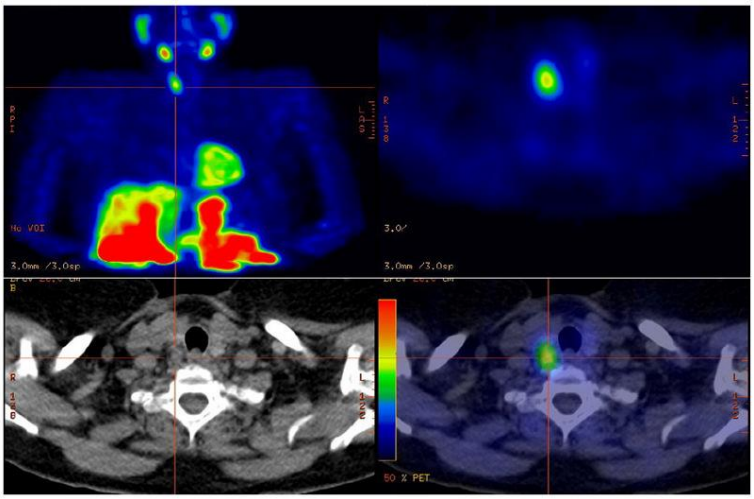


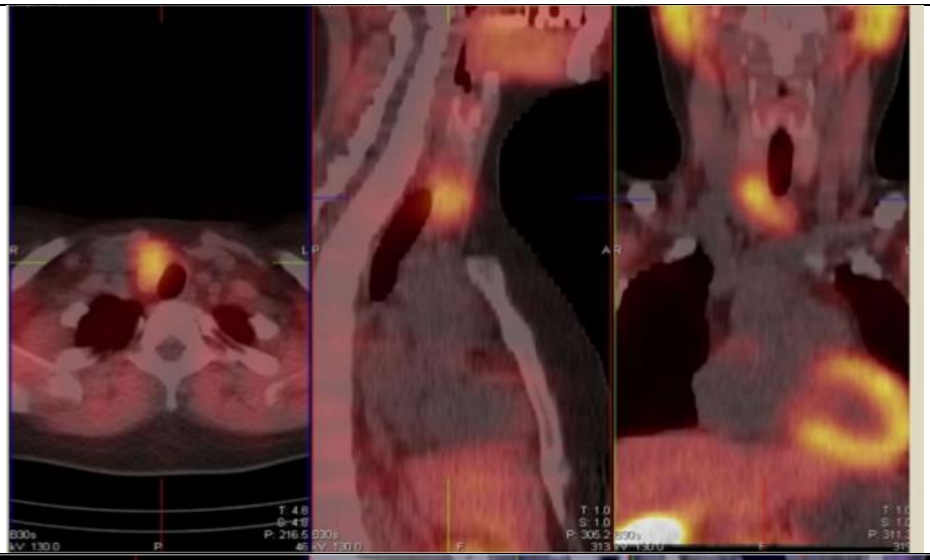


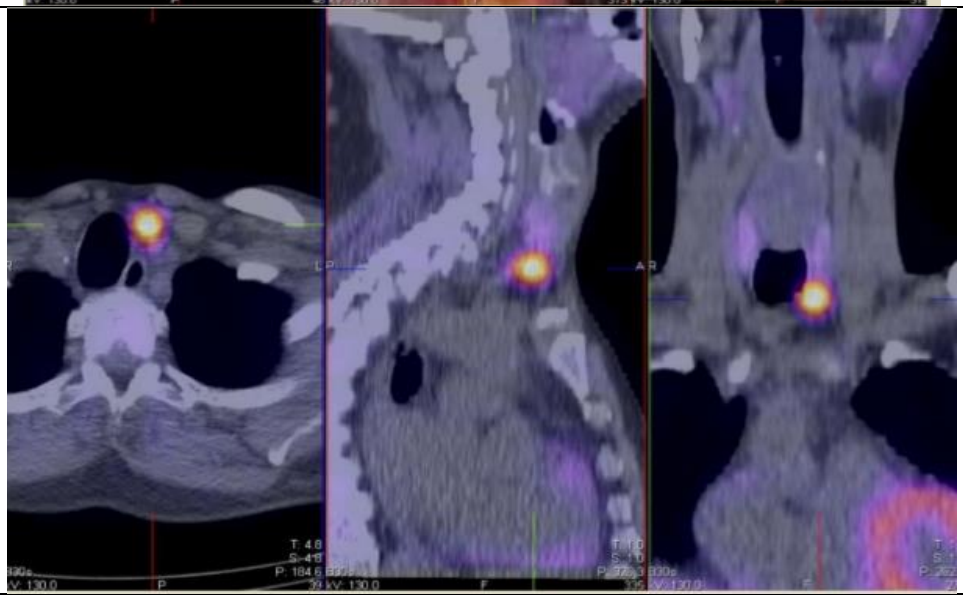
99m Technitium Sestamibi Subtraction Scan



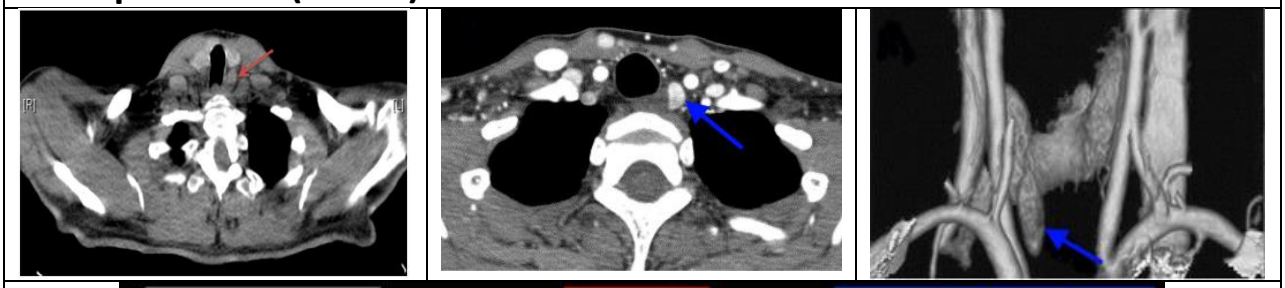
Technitium Sestamibi Subtraction SPECT/CT

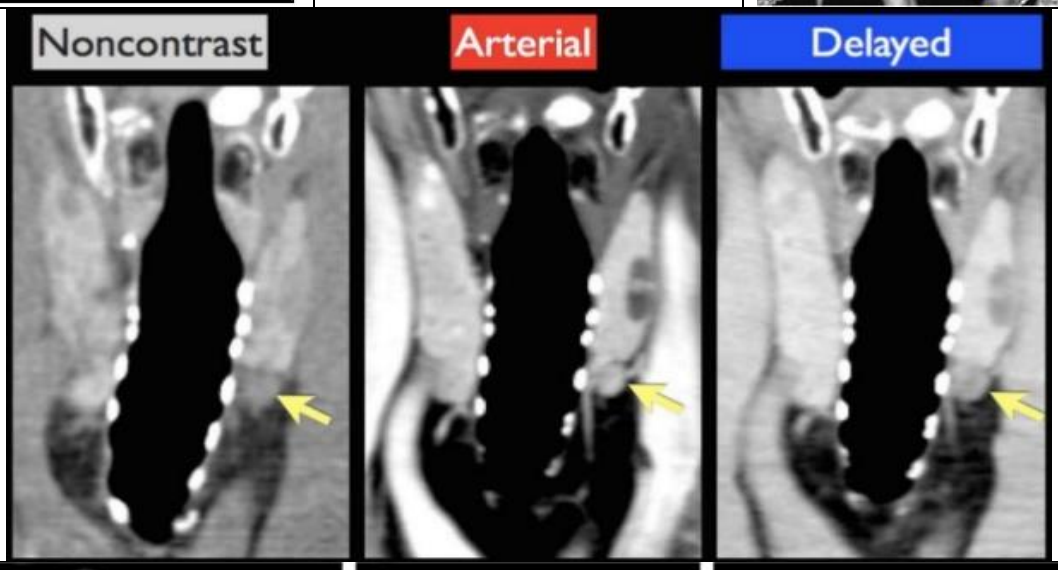


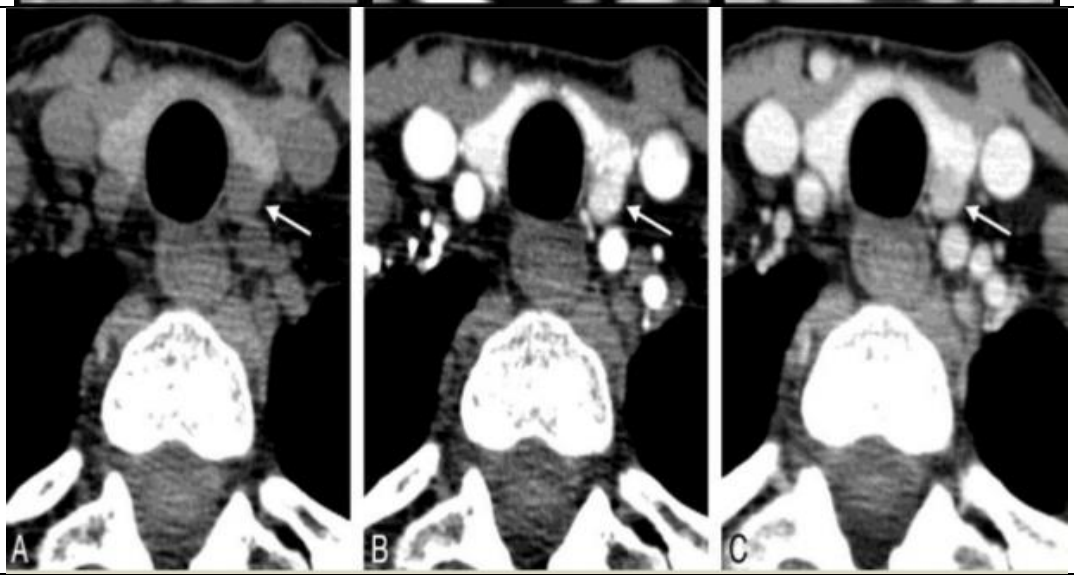


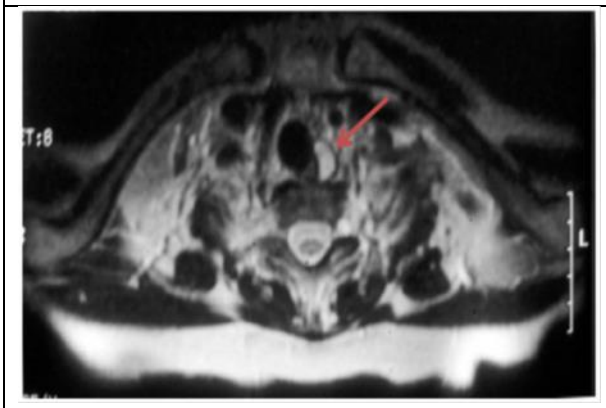
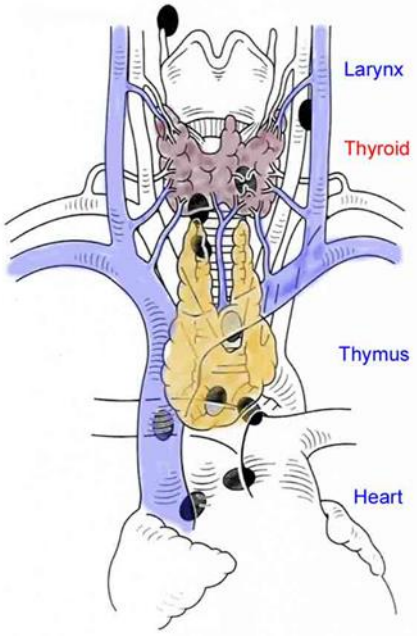


Multiphasic CT (4D-CT)

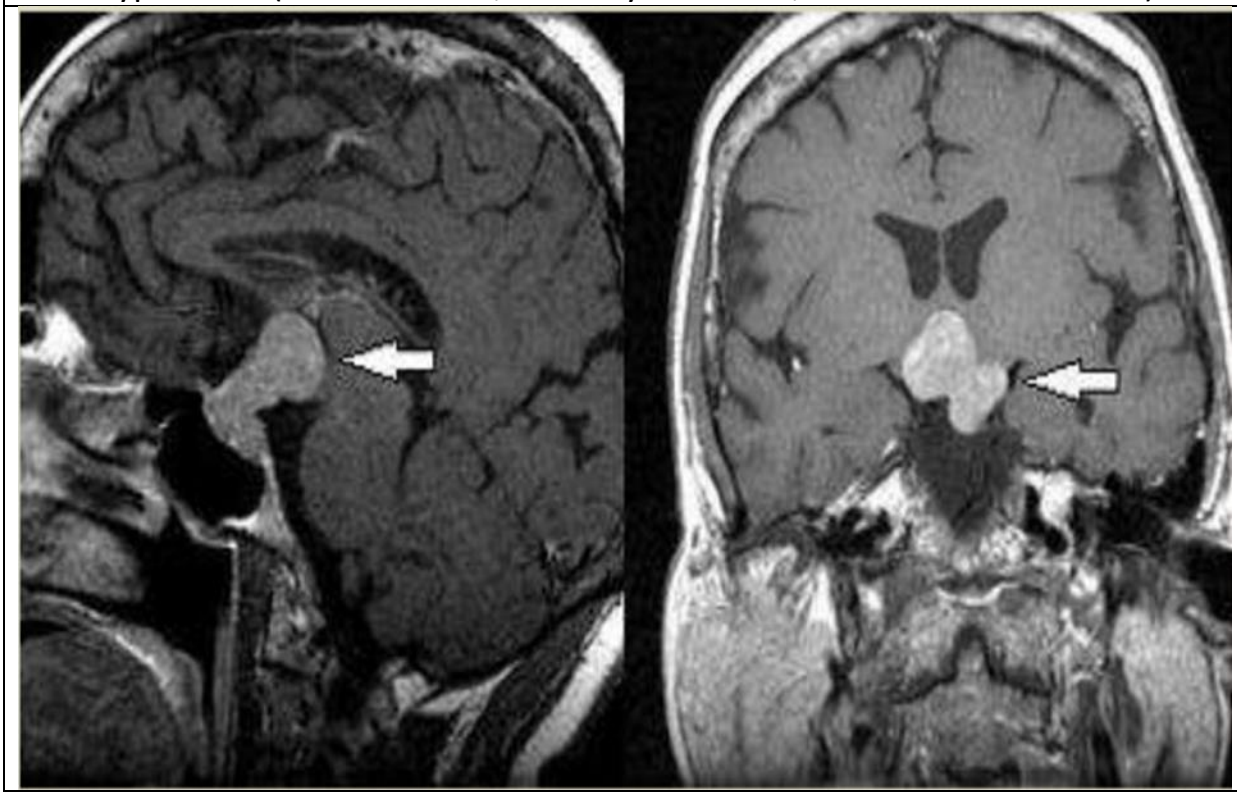






MRI	Ectopic Locations of Parathyroid
	

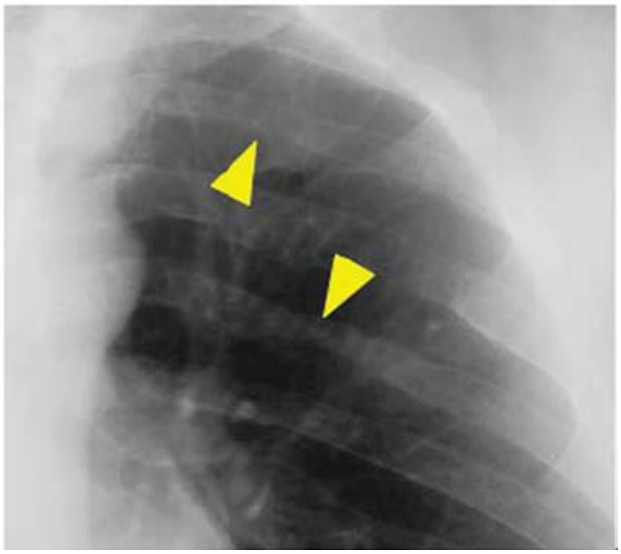
MEN-type I = 3P (PTH adenoma, Pituitary adenoma, Pancreatic islet tumor)



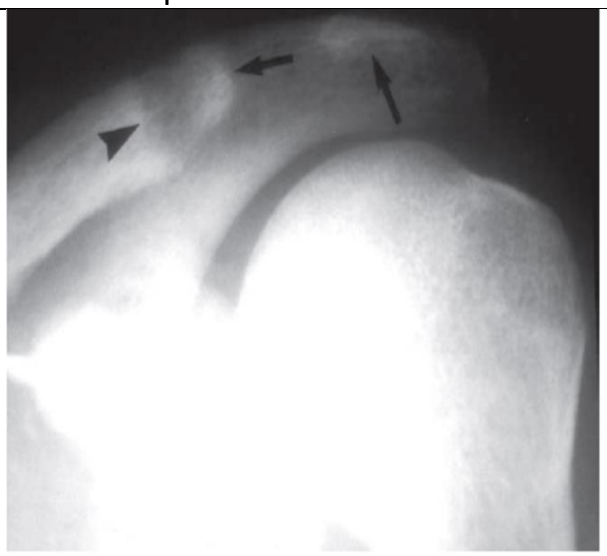
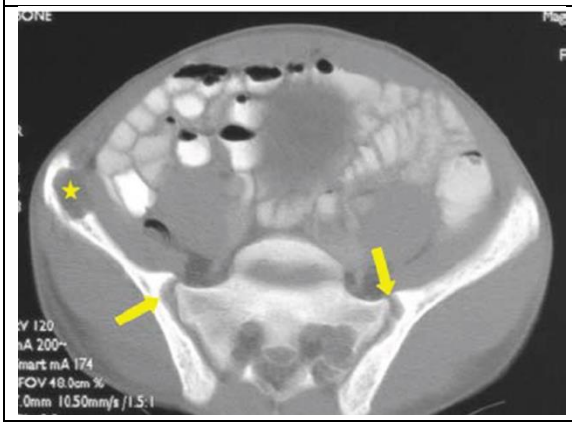
Radiographic features of 1ry HPTH:

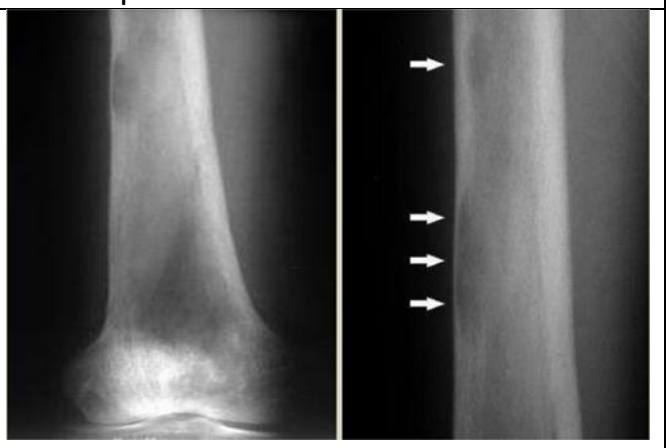
- **Generalized osteopenia**
- **Bone resorption:**
  - **Subperiosteal Resorption.**
  - **Subchondral Resorption.**
  - **Intra-cortical Resorption**
  - **Endosteal Resorption**
  - **Subligamentous Resorption**
  - **Subtendinous Resorption**
- **Acroosteolysis**
- **Loss of lamina dura**
- **Salt and Pepper skull**
- **Ruger jersey of Spine**
- **Brown tumors**

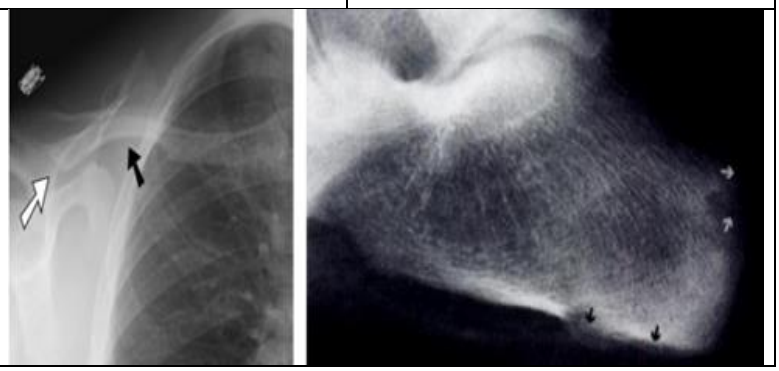
❖ *Subperiosteal Bone Resorption*

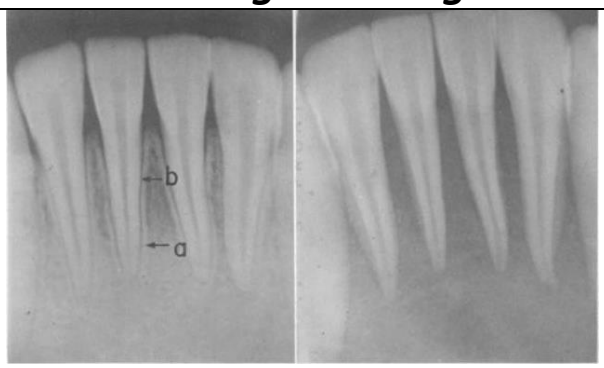
Hands: affects the radial aspects of middle phalanges of middle and index Acroosteolysis	**Superior and inferior rib notching**
	
Knee: medial aspect of proximal tibia	

❖ *Subchondral Resorption*

Metacarpal heads of MCP joints DIP joint (4th or 5th)	Subchondral resorption of ACJ Distal Clavicle Acromion process
	
Subchondral resorption of iliac side of SIJ	**Subchondral resorption of Symphysis Pubis**
	

❖ *Intra-cortical Resorption*	❖ *Endosteal Resorption*
• is manifested by longitudinal striations • A finding known as “tunneling”	• Scalloping of endosteum • Osteopenia with loss of trabecular sharpness
	

❖ *Subligamentous / Subtendinous Resorption*		
Radiographs-smooth and scalloped or irregular		
Pelvis: ○ Greater and lesser trochanters ○ Anterior inferior iliac spine ○ Ischial tuberosity	○ Clavicular insertion of coraco-clavicular ligament	○ Calcaneal insertion of plantar aponeurosis ○ Calcaneal insertion of Achilles tendon.
		

❖ ***Skull*** ***=>"Salt-and-pepper" appearance***	❖ ***Loss of the lamina dura*** ***=> Floating Teeth sign***
	

❖***<u>Spine ("Rugger-jersey")</u>***

- Dense sclerotic bands seen adjacent to the vertebral end plates, giving the vertebrae a sandwich-like appearance.

❖ *Brown Tumors (Osteoclastomas)*

- Caused by localized bone replacement by vascularized fibrous tissue
- May become cystic after necrosis and liquefaction (osteitis fibrosa cystica)

Imaging findings:

- Well defined lytic lesions
- Frequently eccentric or cortical (long bones)
- May cause scalloping and bone expansion
- Sites-:- ribs, pelvis, facial bones and femora, axial skeleton
- May heal after treatment with calcification, sclerosis and lesion disappearance

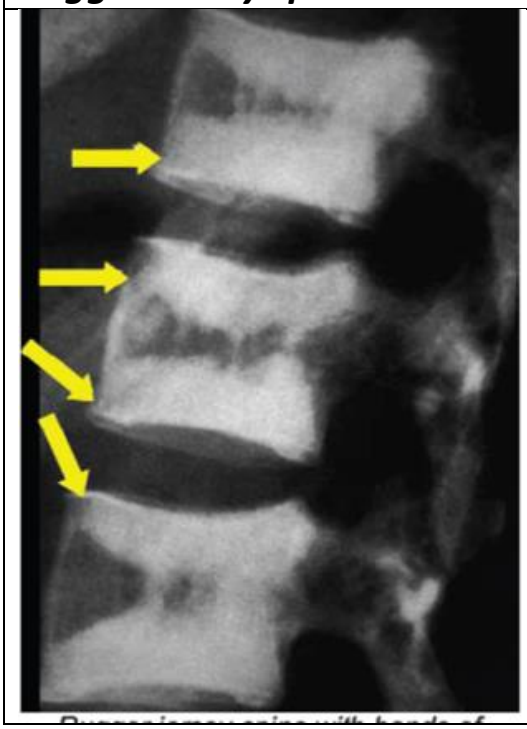
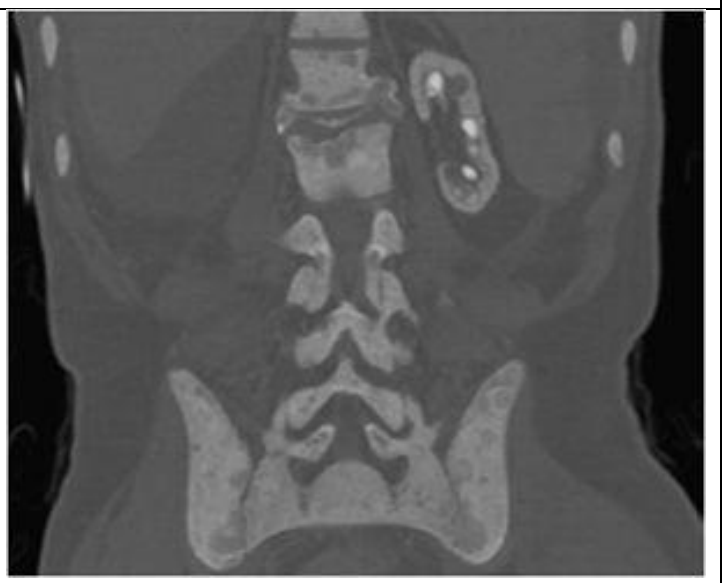
B- Renal osteodystrophy

Musculoskeletal abnormalities that occur in patients with chronic renal failure

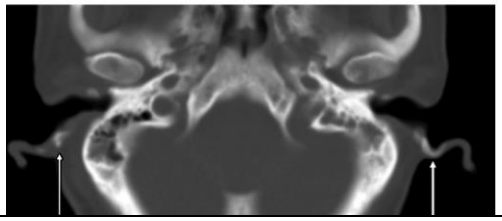
i. **Secondary hyperparathyroidism = 1ry HPTH +**
   - **Osteosclerosis**
     - Rugger Jersey spine
     - Pelvis – ribs - clavicle
   - **Soft tissue & vascular calcifications**

ii. **Osteomalacia**
   - Osteopenia + Losser zones

iii. **Amyloid deposition**
   - can occur in patients undergoing long-term hemodialysis
   - due to b2-microglobulin deposition in bone and soft tissues, including cartilage, joint capsules, ligaments, tenosynovium, muscles, and intervertebral disks.

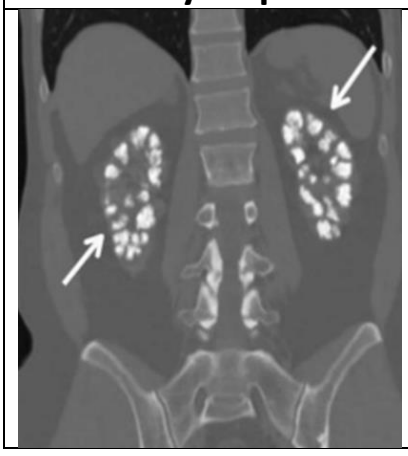
Rugger Jersey spine	***Osteosclerosis***
	

Soft Tissue Calcification



Visceral Calcification

Medullary Nephrocalcinosis



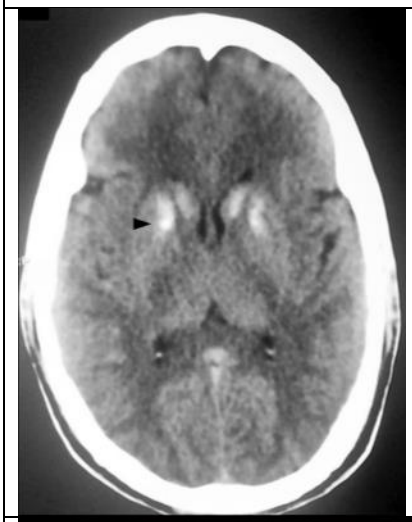
C- Hypoparathyroidism

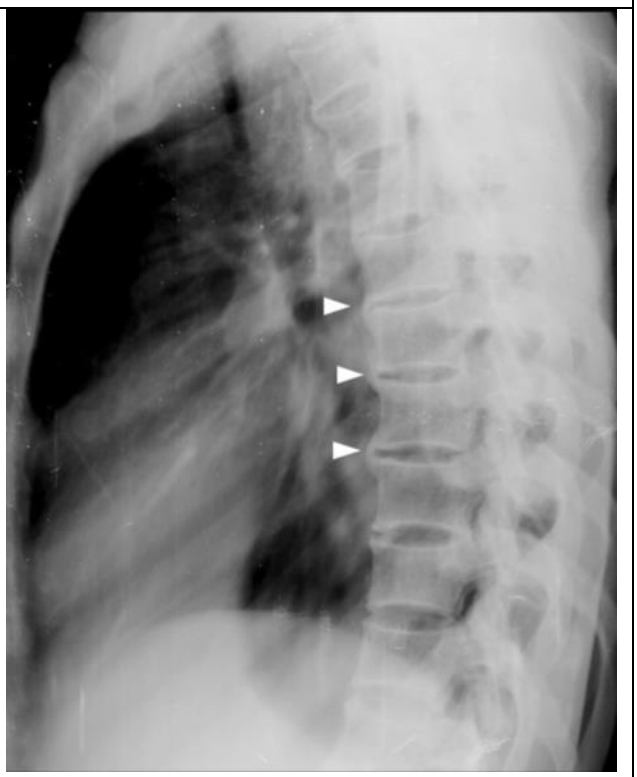
Aetiology:

- Iatrogenic injury: thyroidectomy or parathyroidectomy or during wide excision of a head and neck cancer.
- Autoimmune disease
- Genetic causes (eg, DiGeorge syndrome)

Radiographic findings:

- Generalized or localized osteosclerosis
- Dens metaphyseal bands
- Thickening of the calvaria, with a narrowed diploic
- Subcutaneous calcification (around shoulders and hips)
- In rare cases, spinal ossification similar in appearance to the enthesitis observed in psoriatic arthritis can occur
- CNS: intracranial calcifications: most commonly basal ganglia but also subcortical white matter, corona radiata and thalamus





D- Hypothyroidism

- Deficiency of the thyroid hormones thyroxine and triiodothyronine.
- During fetal life (***Cretinism***)
- During early childhood (***juvenile hypothyroidism***).

❖ Radiographic Findings:

Long Bones:

- Delayed skeletal maturation
- Delayed skeletal growth
- Delayed appearance of 2ry ossification centers
- Delayed epiphyseal closure
- Fragmented 2ry ossification centers => Pseudo fragmentation of epiphysis (DD: Perth's disease)
- Dwarfism.
- Dense transverse metaphyseal bands.

Skull:

- Delayed closure of skull sutures
- Multiple wormian bones
- Brachycephaly
- Poorly developed PNS and mastoid air cells

Sella:

  - Young children: Small bowl shaped sella
  - Older children: large rounded sells (Cherry sella)

Axial Skelton:

- Flattening of vertebral body
- Bullet shaped vertebral body (L1 or L2)
- Increased inter-vertebral distance
- Thoraco-lumbar kyphosis

Pelvis:

- Increased incidence of slipped capital femoral epiphysis (SCFE)
- Narrow pelvis
- Coxa vara deformity

Delayed bone growth and maturation ***Bone age can be assessed by the Greulich & Pyle method with PA left hand radiograph***	**Pseudo-fragmentation of both capital femoral epiphyses.** DD Legg-Calvé-Perthes disease
Enlarged sella Hypoplastic maxillary and frontal sinus	**Bullet shaped vertebra** Increased inter vertebral spaces

E- Hyperthyroidism

- Hyperthyroidism is most commonly due to oversecretion of thyroid hormone by the thyroid gland diffusely (Graves disease) or focally (single or multiple adenomas).
- Skeletal manifestation of hyperthyroidism is osteoporosis.

Thyroid Acropachy

- Generalized osteoporosis
- Prominent smooth flowing **periosteal reaction** affecting the hands and feet.

Location & Distribution:

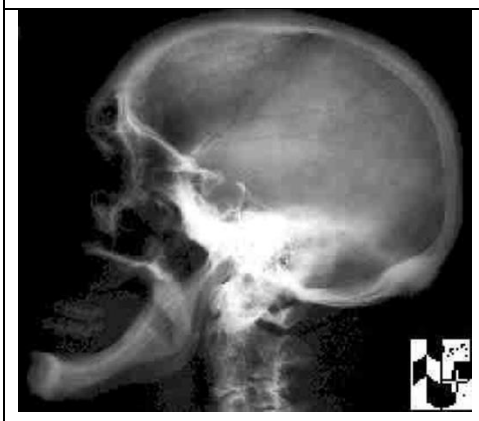
- Bilateral and symmetrical involving **tubular bones of hands and feet**
- Soft tissue swelling may also be seen in the pretibial region.

F- Acromegaly

- Excess GH due to anterior pituitary adenoma/ hyperplasia
- Gigantism in children

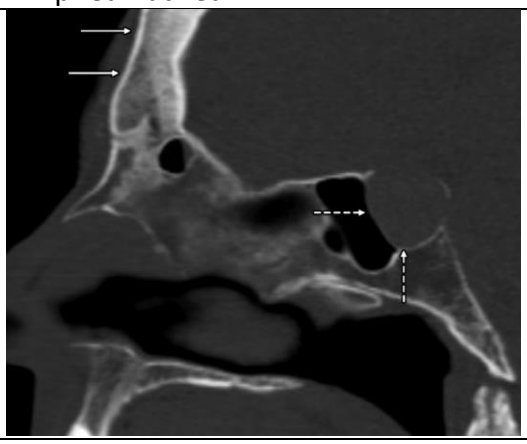
Skull

- Thickening of the cranial bones
- Increased density.
- The diploic space may be obliterated.
- The prognathous jaw.



Sella

- The sella turcica, may or may not be enlarged.
- The paranasal sinuses become enlarged
- The mastoid cells become over pneumatized.



Spine

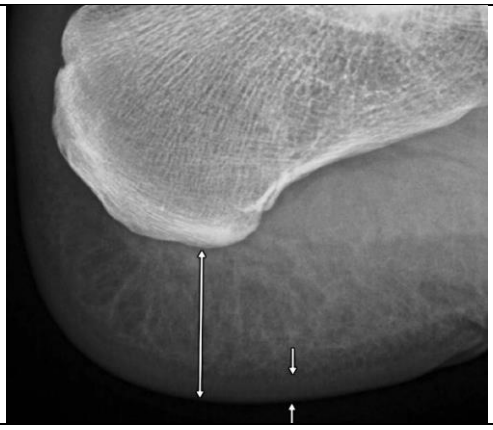
- Increase AP diameter of a vertebral body
- Scalloping or increased concavity of the posterior vertebral margin
- Thoracic kyphosis is often increased
- Lumbar lordosis is accentuated.
- The invertebral disk space may be wider than normal because of overgrowth of the cartilaginous portion of the disk

Hands

- Spade-shaped tufts
- Hypertrophy of the soft tissues, leading to the development of square, spade-shaped fingers
- Increase in the size of the sesamoid at the metacarpophalangeal joint of the thumb
- Sesamoid index (=the height and width of this ossicle)
  > 30mm in women, > 40mm in men
- The joint spaces widen as a result of hypertrophy of articular cartilage
- Distal phalanges: their bases enlarge and the terminal tufts form spur-like projections.
- Heads of the metacarpals are enlarged and irregular bony thickening along the margins, simulating osteophytes.

Foot

- Heel-pad thickness > 22mm
- This index is determined by the distance from the posteroinferior surface of the os calcis to the nearest skin surface.
- Thick plantar skin (arrows).



Hematological Bone Disease

A- Thalassemia

- Thalassaemia is an autosomal recessive haemoglobinopathy that originated in the Mediterranean region.

i) Medullary Hematopoiesis:

Medulla:

- Medullary expansion
- Destruction of medullary trabeculae
- Prominent remaining trabeculae

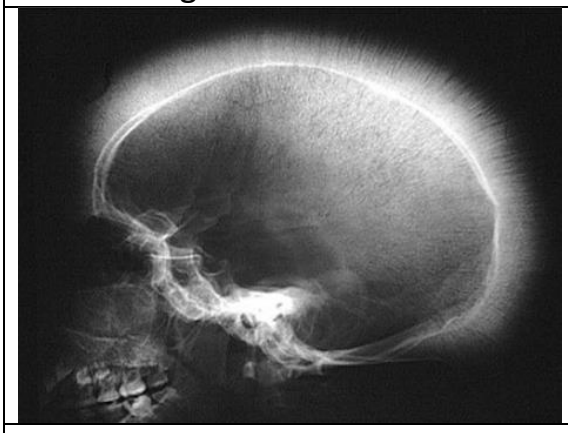
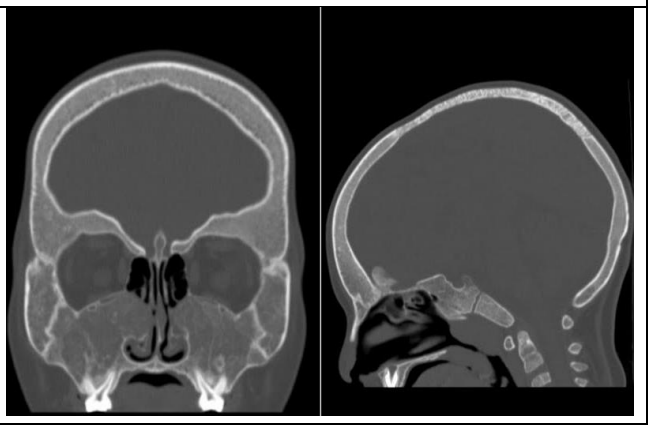
Cortex:

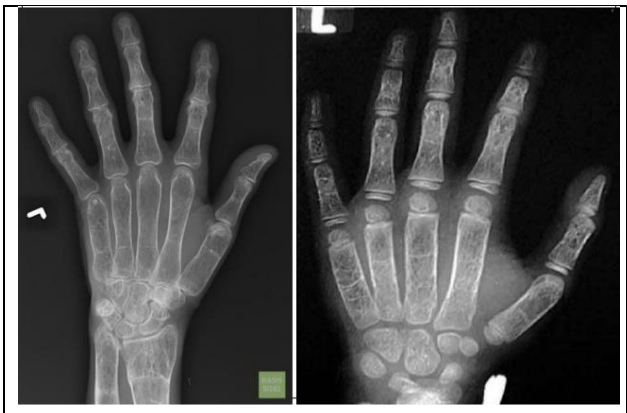
- Thinning
- Expansion

Bone: Remodeling

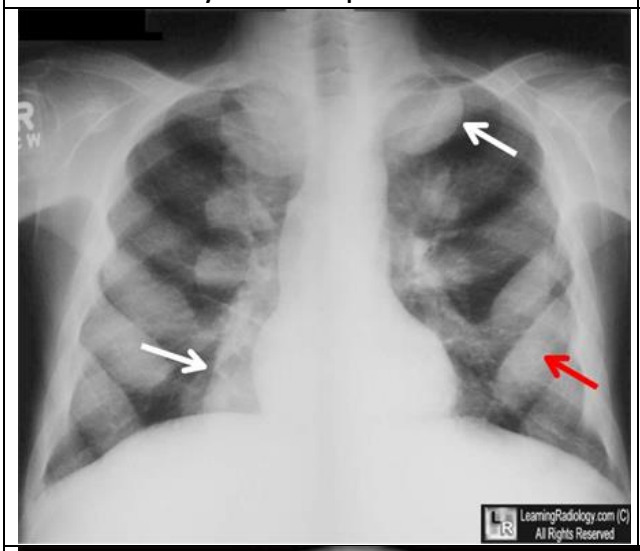
ii) Extra-Medullary Hematopoiesis:

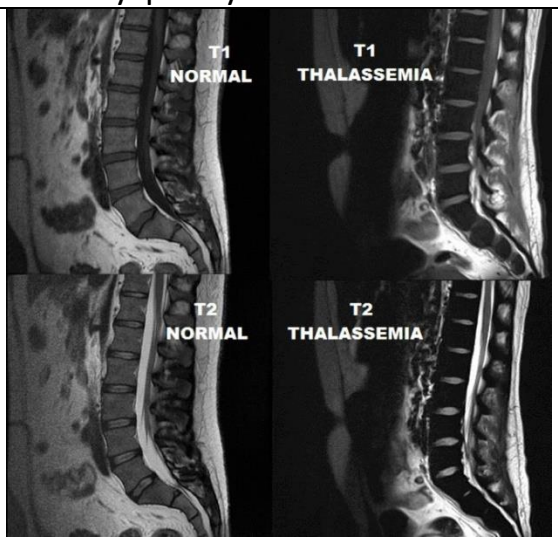
- Hepatosplenomegaly
- Para-vertebral soft tissue masses

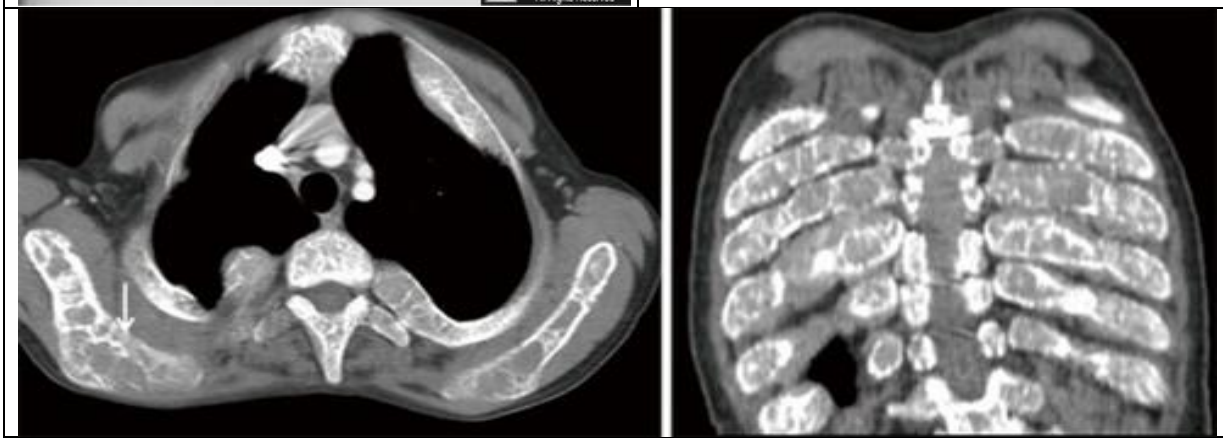
Skull	**Facial bones**
• **Hair on end appearance** • Granular osteoporosis • Widening of diploic space • Thinning of inner and outer tables	• Hypo-pneumatization / Obliteration of PNS • The ethmoid sinuses are spared due to lack of red bone marrow
	
Shot bones of Hands & Feet	**Long bones**
Box like digits	***Erlenmeyer flask deformity***



Chest Wall	Spine
• Ribs: rib-within-a-rib appearance, noted particularly in the middle and anterior portions of the ribs • Para-spinal masses of extra-medullary hematopoiesis.	• Diffuse osteoporosis • Diffusely low signal throughout the bony skeleton on both T1 and T2 sequences. • Platyspondylosis







B- Sickle cell Disease

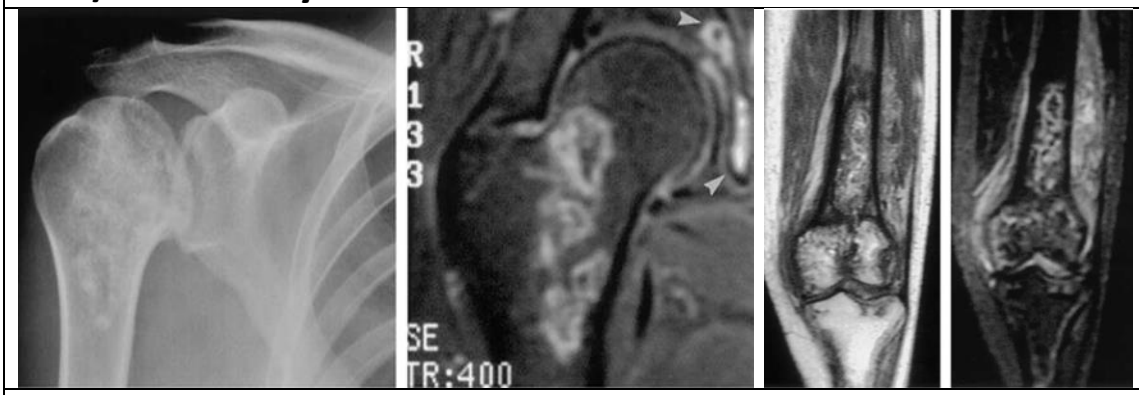
- Sickle cell anemia (SCA) is a hemolytic anemia characterized by abnormally shaped (sickled) red blood cells (RBCs), which are removed from the circulation and destroyed at increased rates, leading to anemia.

Skeletal Manifestation of Sickle Cell Anemia:

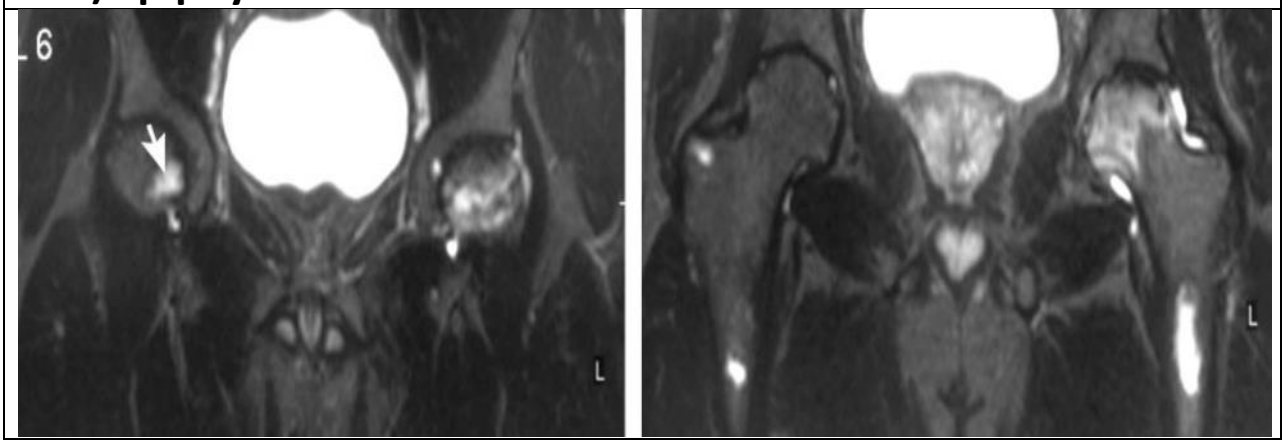
i) Medullary and Extra-medullary Hematopoiesis (as Thalassemia)

ii) Bone Infarction => Diagnostic hallmark

1) Medullary bone infarcts



2) Epiphyseal Infarction = Osteonecrosis of femoral head

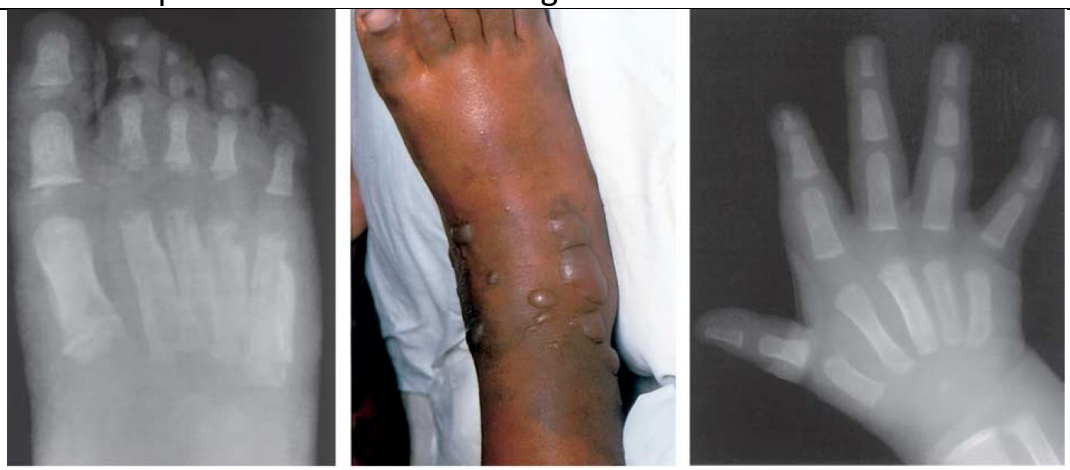


3) H-shaped Vertebrae

- Central, square shaped endplate depression
- Resulting from microvascular endplate occlusion
- Sharp steplike appearance of the vertebral endplate

4) Sickle Cell Dactylitis = Hand-foot Syndrome

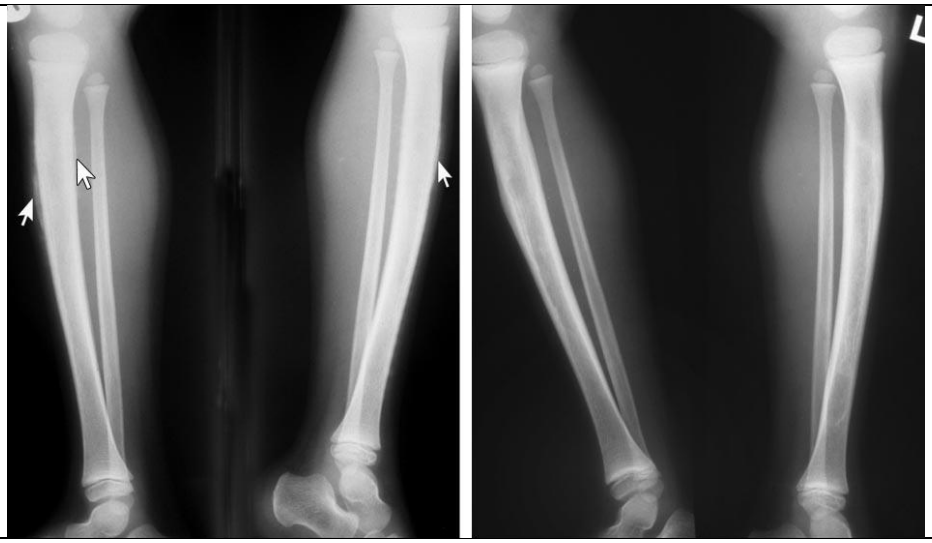
- Term used to describe painful, swollen hands and feet accompanied by fever.
- It is most often seen in children younger than 4 years of age
- Dactylitis is often the first clinical manifestation of SCA
- Extensive infarction of marrow, medullary trabeculae, and inner layers of cortical bone
- Periosteal reaction and subperiosteal new bone formation.
- Massive and painful soft tissue swellings



5) Cortical Bone Infarction

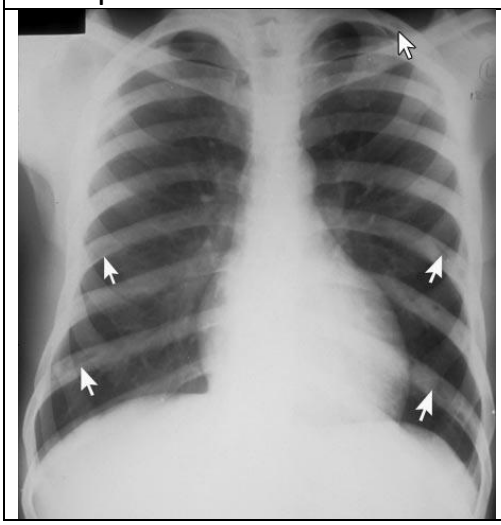
- Subperiosteal new bone may form either through:
- Incorporation into existing cortical bone => thickening of the cortex
- Layered deposits along the inner surface of the cortex

  ⇨ ***Laminated, "bone-within bone" appearance***



6) Rib Infarction

Dense sclerosis of the rib cage, with areas of lucency (arrows) in multiple ribs.



7) Pelvic Infarction

Increased bone density
Dystrophic calcification

iii) Osteomyelitis

- Patients with SCA and osteomyelitis present with pain, fever, erythema, and an elevated white blood cell count.
- The most commonly encountered organism is Salmonella, followed by S aureus.

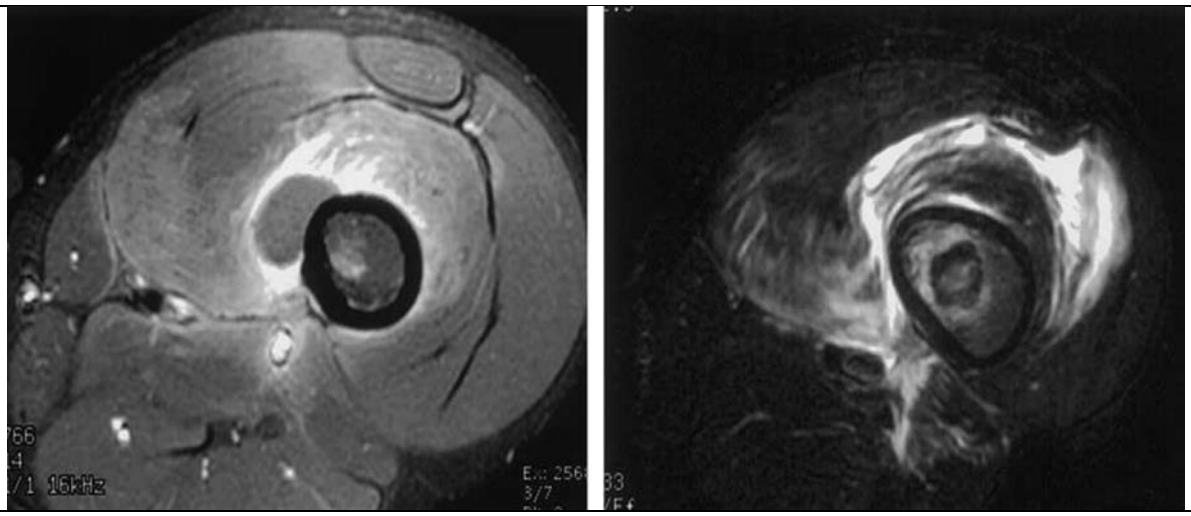
Acute Osteomyelitis: Radiographic features are nonspecific and initially are often normal. Mottled attenuation Diffuse periostitis	Sclerosis with an area of central lucency, likely representing subacute or chronic abscess

Role of Dynamic or triple-phase 99mTc MDP scintigraphy:

usually shows a combination of increased perfusion, hyperemia, and osteoblastic activity that results in increased uptake during all three phases

Role Of MRI

Heterogeneous enhancement of the marrow cavity, a rounded low-signal-intensity area adjacent to the shaft that is nonenhancing (representing a fluid collection), and enhancement of the soft tissues around the shaft and of the adjacent musculature.



iv) Septic arthritis

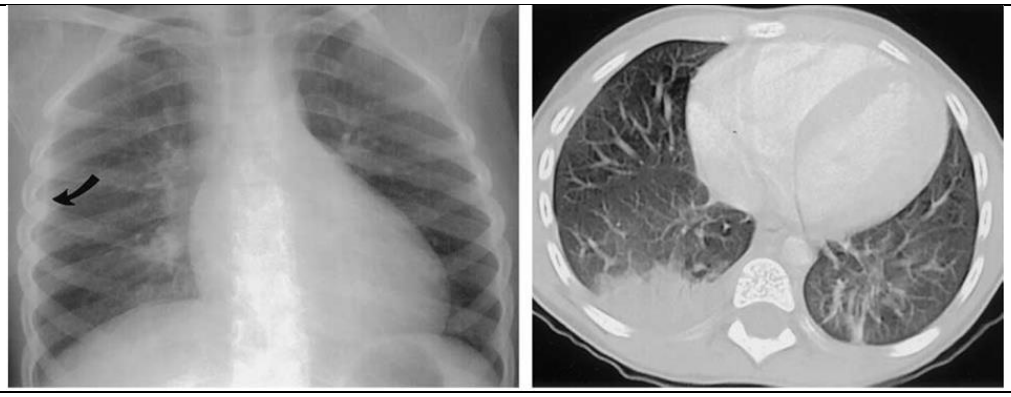
- is less common than osteomyelitis.
- It often arises in conjunction with vaso-occlusion and bone infarction.
- Aseptic joint effusions are relatively common in association with painful bone crises
- Needle biopsy with aspiration of fluid from the joint is important in the diagnosis of infection.

v) Muscle and Soft- Tissue Involvement

- Soft-tissue involvement is seen with bone infection.
- In osteomyelitis, associated fluid collections that communicate with marrow through cortical defects are seen.
- Sinus tracts that open out onto the skin
- Leg ulcers, particularly over bony prominences, are common in sickle cell disease as a result of venous stasis and tissue hypoxia

❖ Pulmonary Manifestation of SCA:

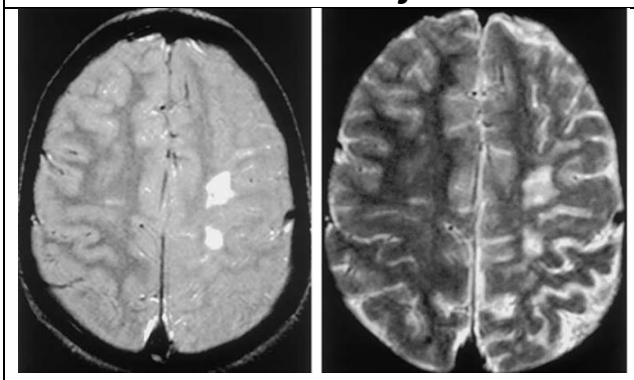
- The lung is a common site of involvement in SCA.
- Pneumonia
- Acute chest syndrome (ACS) = pulmonary consolidation and some combination of fever, chest pain, and signs of pulmonary compromise such as cough, dyspnea, and tachypnea.
- Pulmonary fibrosis.
- Pulmonary complications constitute the second leading cause of hospitalization (after acute pain crises) and are now the leading cause of death for patients with SCA

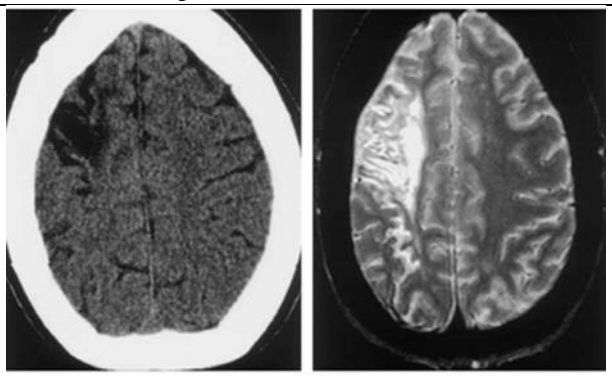


❖ Neurological Manifestations of SCA

- Stroke, atrophy, and cognitive impairment
- Intraparenchymal and subarachnoid hemorrhage and aneurysm

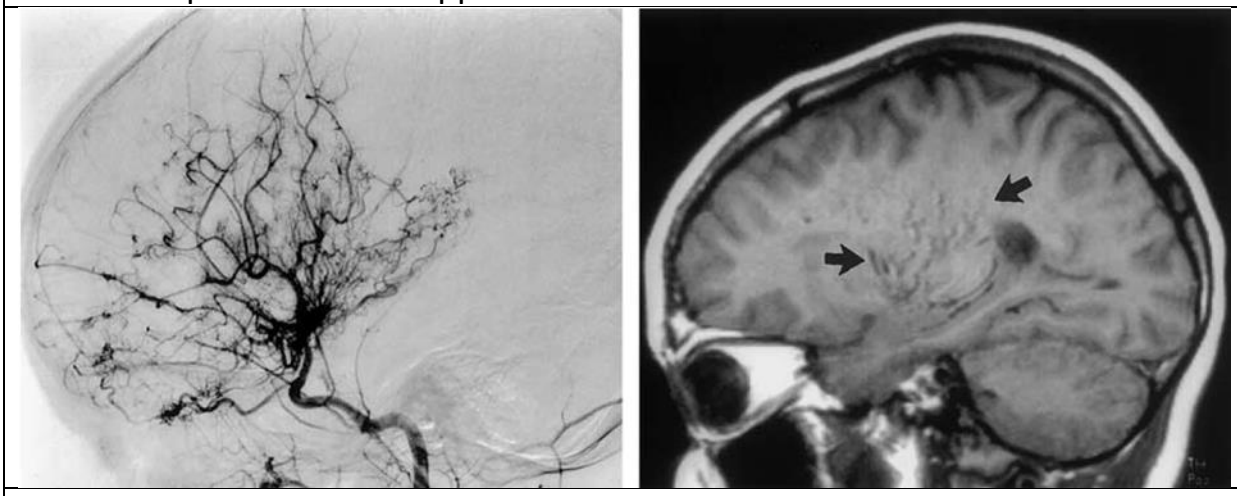
Silent white matter infarct	***Chronic Infarct***





❖ Moyamoya disease in SCA

- Common carotid angiogram reveals occlusion of the supraclinoid ICA and multiple small collateral vessels arising from the distal internal carotid artery and extending into the regions of the basal ganglia and thalamus, giving the classic “puff of smoke” appearance.



❖ Spleen

Splenic infarction, which progresses over time to functional autosplenectomy.

- The infarcted spleen is replaced by fibrosis, with calcium and hemosiderin deposition.
- As splenic function is lost, uptake of Tc-99m sulfur colloid diminishes and may totally disappear
- This has important consequences for infection susceptibility.
- Patients with SCA are prone to infection with S pneumoniae, H influenzae type B, and Salmonella, Klebsiella, and other encapsulated bacteria

Ssequestration syndrome.

- It is characterized by rapid pooling of blood within a solid organ (almost always the spleen), with resulting intravascular volume depletion and dropping hematocrit values (a drop of >2 g/dL is considered significant).

Renal:

- Papillary necrosis
- Glomerulosclerosis may lead to proteinuria, nephrotic syndrome and sometimes renal failure

Liver: Hepatitis is also frequent, likely from repeated transfusions

GB: Pigmented gallstones

C- Myelofibrosis

- Myelofibrosis is characterized by:
  - Anemia
  - Splenomegaly
  - Extramedullary hematopoiesis (EMH),
  - Leukoerythroblastosis, anisopoikilocytosis, and teardrop poikilocytes.
  - Bone marrow is usually hypocellular, with increased amounts of reticulin and collagen and progressive fibrosis.

- Age: Middle-aged to elderly, with a mean age of 60 years

Myelofibrosis is a myeloproliferative disorder:

- Primary (or idiopathic): disorder of unknown origin.
- Secondary: BM replacement from malignancy/toxins

Distribution:

- Axial Skeleton: especially spine, pelvis, ribs
- Long bones.

Imaging findings:

- Osteosclerosis
- Hepatosplenomegaly
- Lymphadenopathies
- Extramedullary hematopoiesis (EMH)

Radiographic Findings:

- Osteosclerosis: The osseous structures may be uniformly dense or demonstrate small areas of relative radiolucency
- Cortical thickening can be observed, due predominantly to endosteal sclerosis
- Obliteration between cortical and medullary bone
- Increased radiodensity or condensation of bone at the superior and inferior margins of the vertebral body (sandwich vertebrae

MRI Findings:

Normal fatty marrow:

T1: high signal intensity

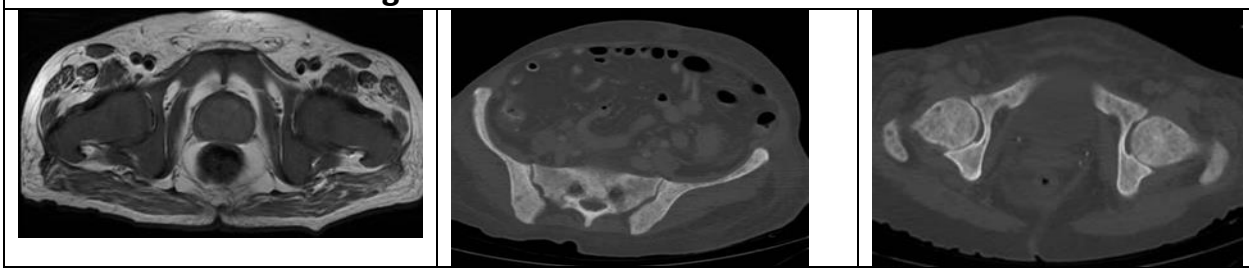
T2: iso- or slightly high signal intensity

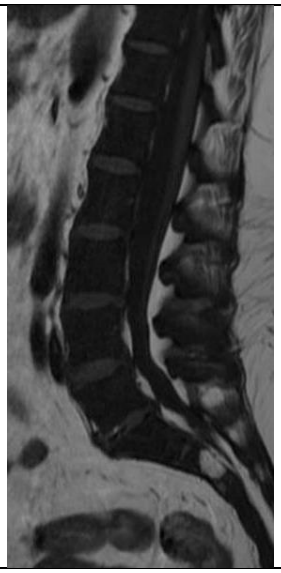
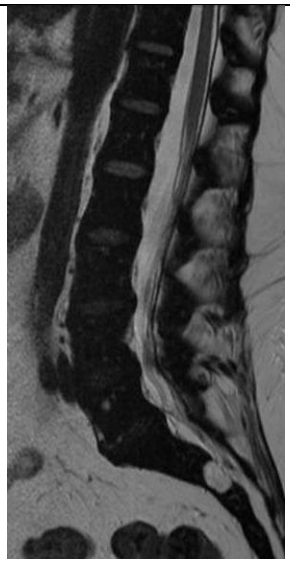
Myelofibrosis:

T1 & T2: very low homogeneous signal

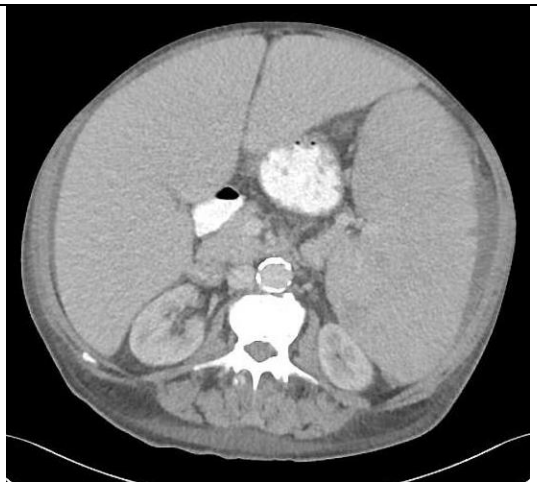
Pelvis MRI: Diffuse marked heterogeneous decreased signal of bone marrow

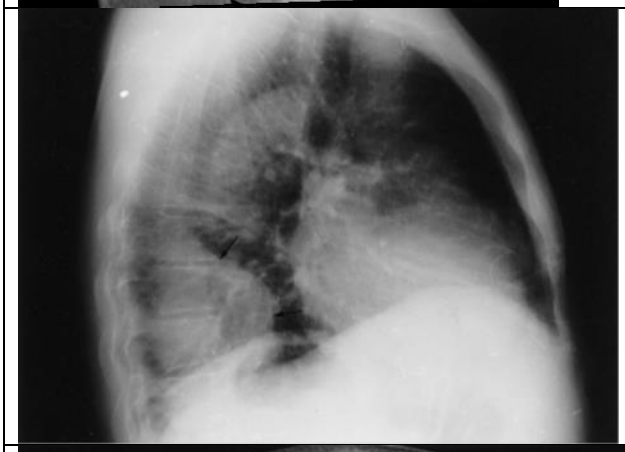
Pelvis CT: Diffuse homogeneous osteosclerosis

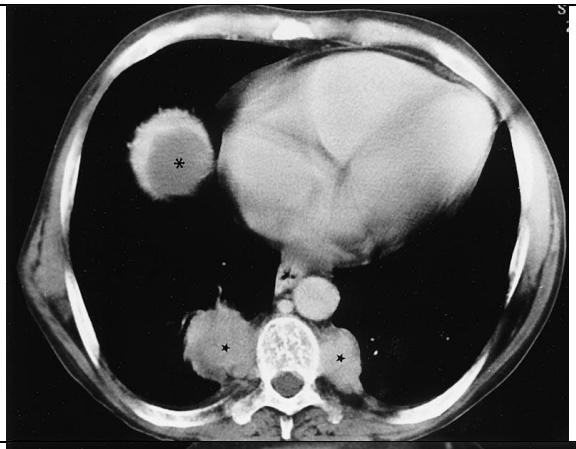


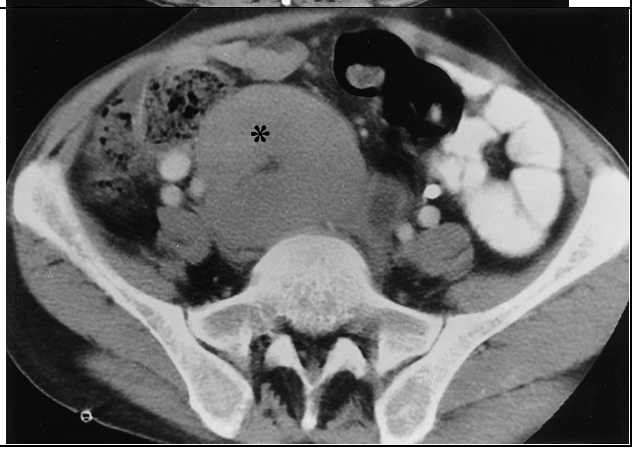
Spine Xray: Diffuse homogeneous osteosclerosis	**Spine MRI: Diffuse marked heterogeneous / homogenous decreased signal of bone marrow**		
X-ray	**T1**	**T2**	**STIR**
			

Extra-Medullary hematopoiesis









D- Systemic Mastocytosis

- Systemic mastocytosis comprises a group of clonal disorders of the mast cell that most commonly involves the skeletal system

Clinical features:

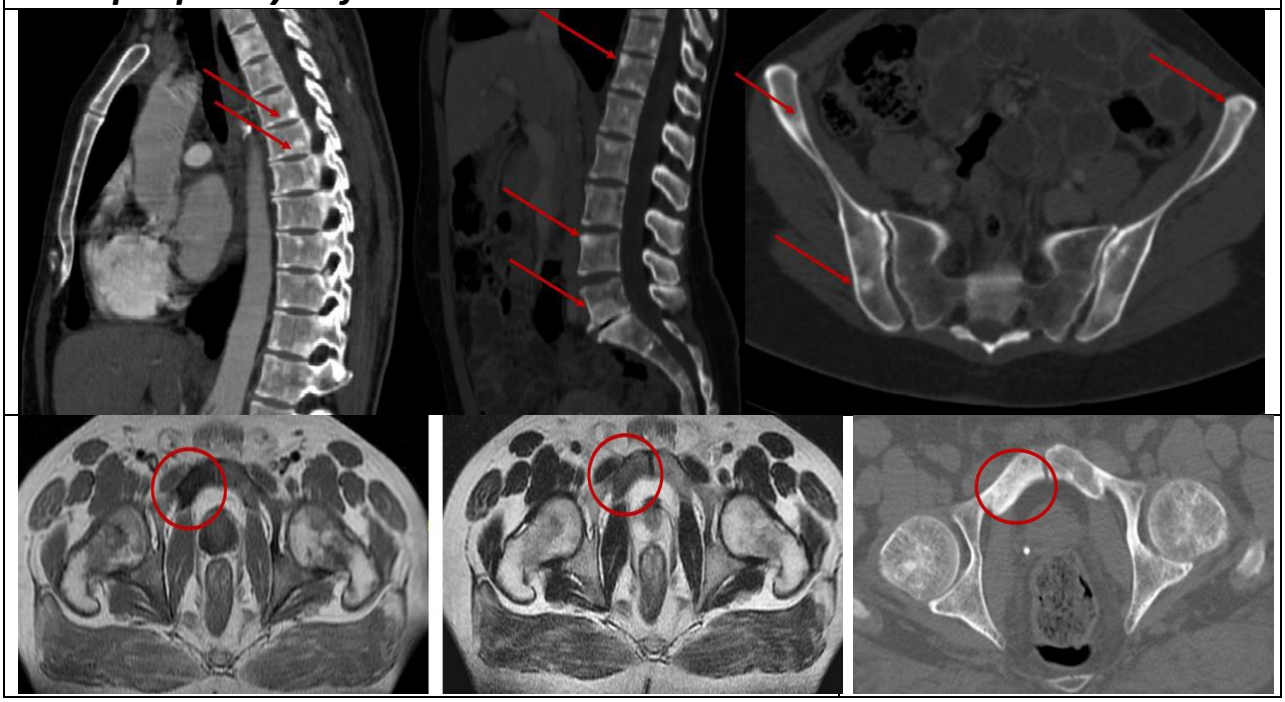
- Cutaneous manifestations
- Flushing
- Hypotension and syncope
- Abdominal pain
- Nausea, vomiting and diarrhea
- Malabsorption
- Bone pain and pathological fractures
- Associated haematological disorders

Age: 5th to 8th decades of life.

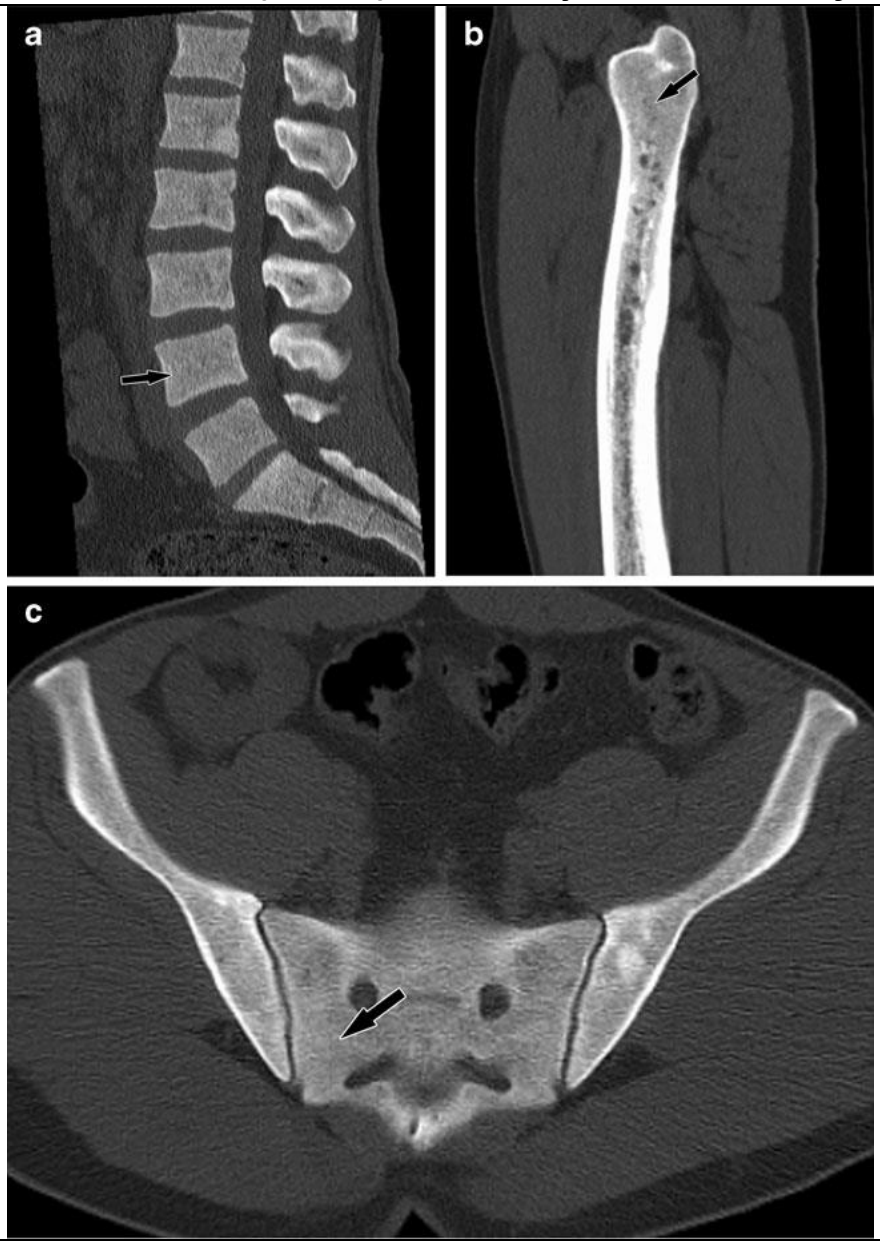
Radiological Findings:

- Atypical osteopenia
- Osteosclerotic
- Mixed lytic and sclerotic

Multiple poorly defined sclerotic lesions



Diffuse marrow sclerosis (arrow) secondary to mast cell infiltration



E- Musculoskeletal Lymphoma

- Primary bone lymphoma is a less common manifestation of lymphoma than secondary involvement from disseminated lymphoma.
- Osseous involvement is indicative of widespread, aggressive disease with a poor prognosis because it is usually associated with the most unfavorable histologic subtypes
- Involvement of the bone marrow indicates **stage IV disease**.
- HD: marrow involvement is rare (5-15% of patients)
- NHL: marrow involvement is more common 20-40% of patients)

Primary bone lymphoma:

- < 5% of all primary bone tumors
- <1% of non-Hodgkin lymphoma.

Secondary bone lymphoma:

- 15% of disseminated lymphomas.

locations (in decreasing order of frequency):

- Dorsolumbar spine – Pelvis – Ribs – Femora – Sternum

1) Lytic-Destructive Pattern

The lytic pattern may be:

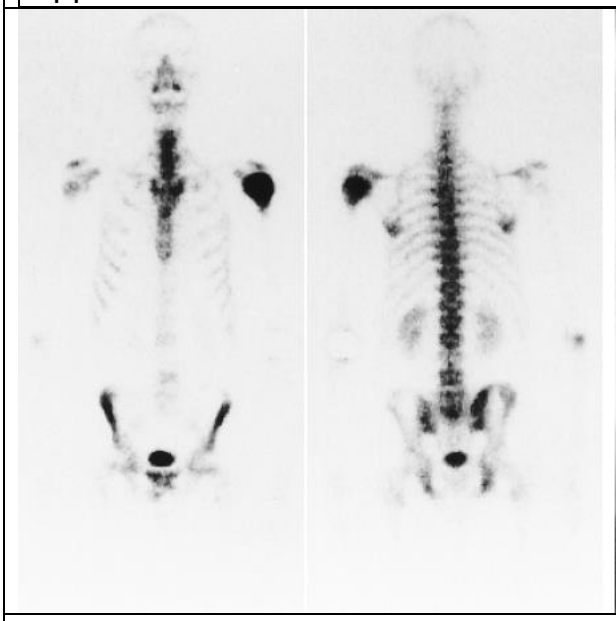
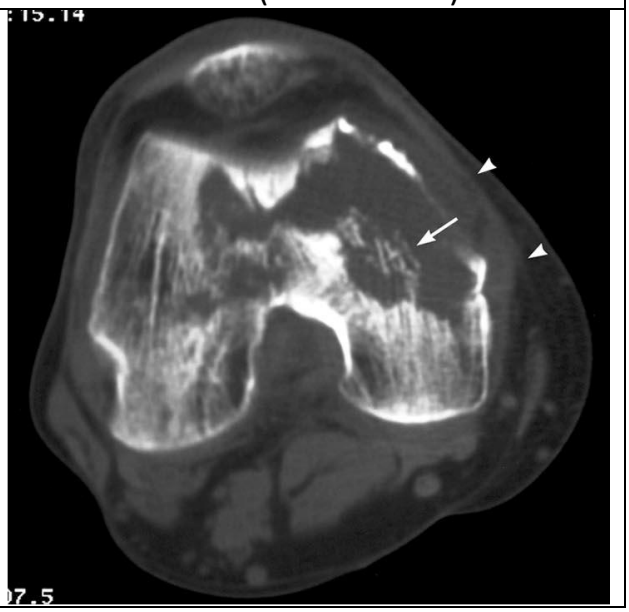
- **Permeative**: characterized by numerous small, elongated rarefactions that are parallel to the long axis of the bone and relatively uniform in size
- **Moth-eaten:** a pattern of many medium to large areas of radiolucency in a poorly marginated area of bone

MRI Findings:

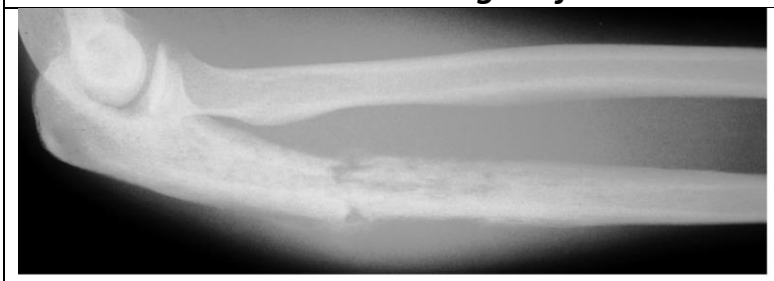
- Ill-defined medullary lesion
- T1: Heterogeneous low signal
- T2: Heterogeneous high signal
- +C: Heterogeneous enhancement

- Cortical breakthrough
- Pathologic fractures
- Periosteal reaction:
  - Lamellated or layered (also called onion-peel appearance)
  - Broken, when discontinuous or interrupted periosteal new bone is seen

Lytic permeative pattern => Sclerotic changes related to therpay

Bone scintigrams demonstrate markedly increased activity in the upper end of the left humerus.	Anteroposterior radiograph of the left humerus shows an ill-defined geographic area of bone destruction
	
Right medial femoral condyle mottled appearance + destruction of the medial femoral condyle + Cortical erosion + small soft-tissue mass (arrowheads).	
	

Cortical destruction + Pathological fracture



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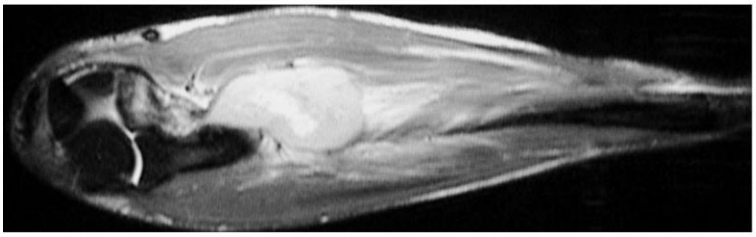

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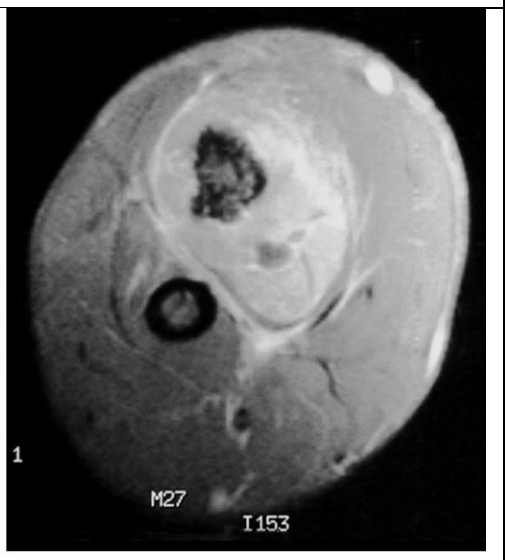
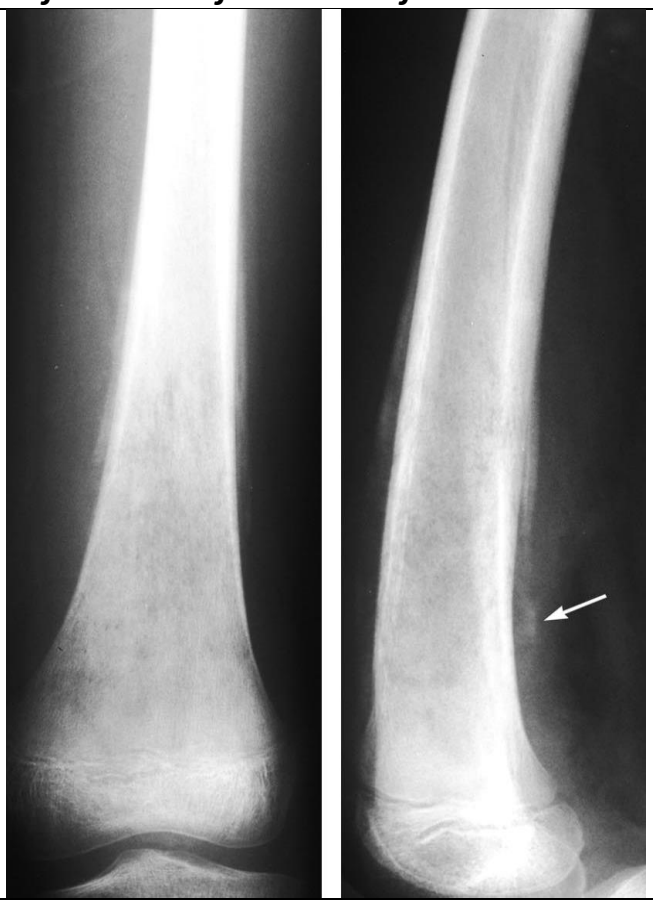


c.

Permeative changes of the distal femoral shaft + Periosteal reaction



2) Blastic-Sclerotic Pattern

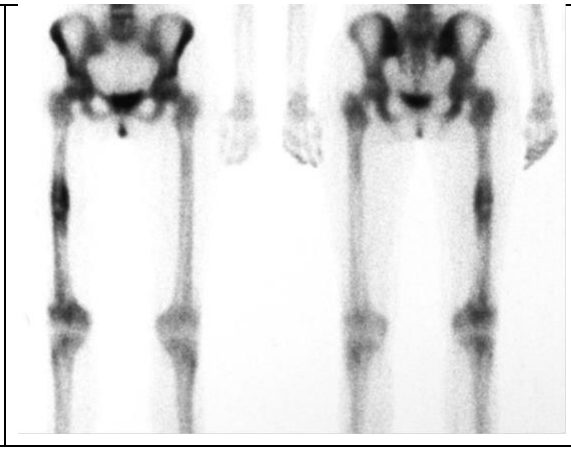
- Primarily blastic-sclerotic lesions are rare
- Mixed lytic and sclerotic areas can be seen
- Sclerotic areas can develop in an originally lytic pattern after therapy (irradiation and chemotherapy).

3) Ivory vertebrae

4) Subtle or "Near-Normal" Findings

- Near absence of detectable abnormalities on plain radiographs
- Normal-appearing radiographs
- Striking abnormalities on radionuclide bone scans and MR images

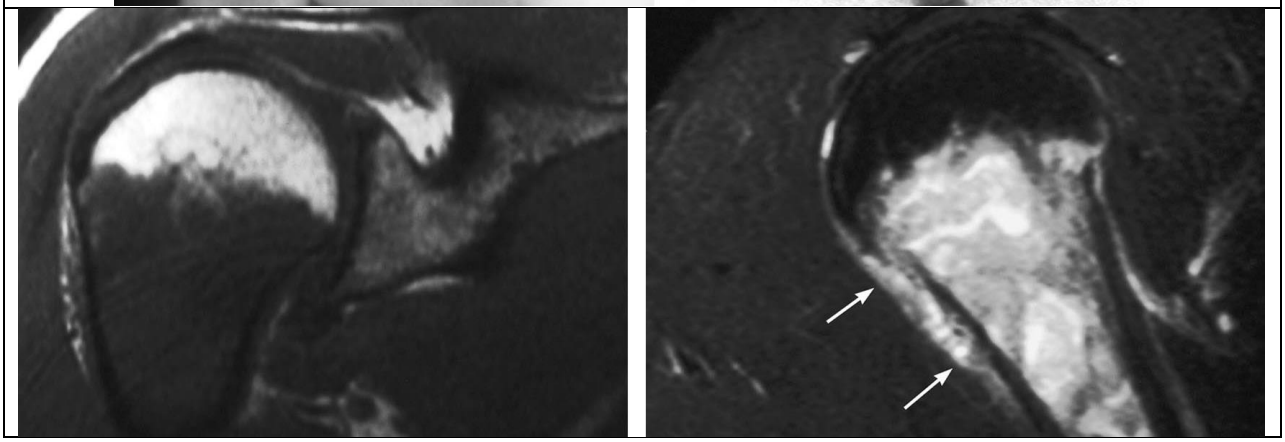
- MRI of bone marrow infiltration:
- T1: Low signal
- T2/STIR: High signal
- +C: Enhancement.



5) Soft-Tissue Involvement

- Soft-tissue masses represent a more aggressive pattern of involvement and a poorer prognosis
- Nearly all cases that had a permeative pattern were associated with soft tissue masses on MR images

- T1: Intermediate signal
- T2/STIR: high signal
- +C: variable enhancement

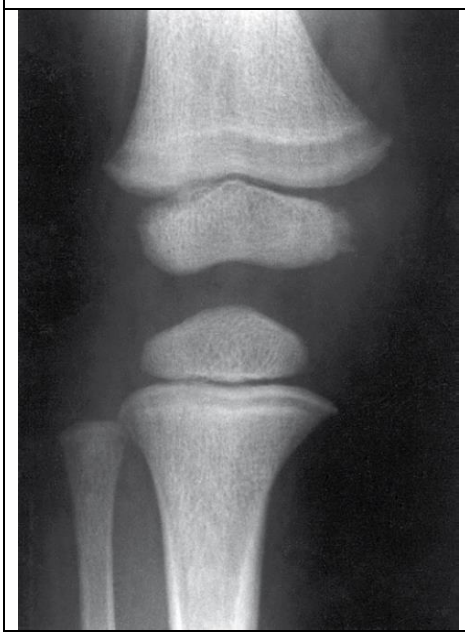
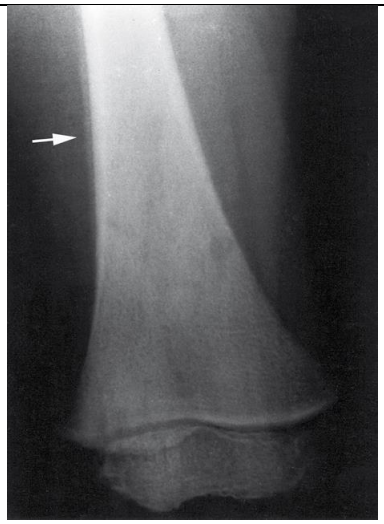


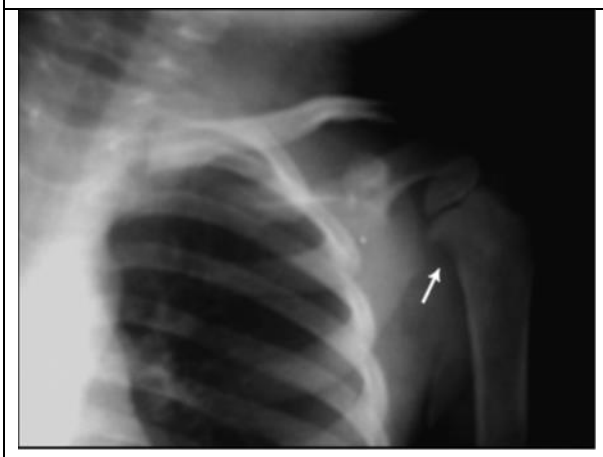
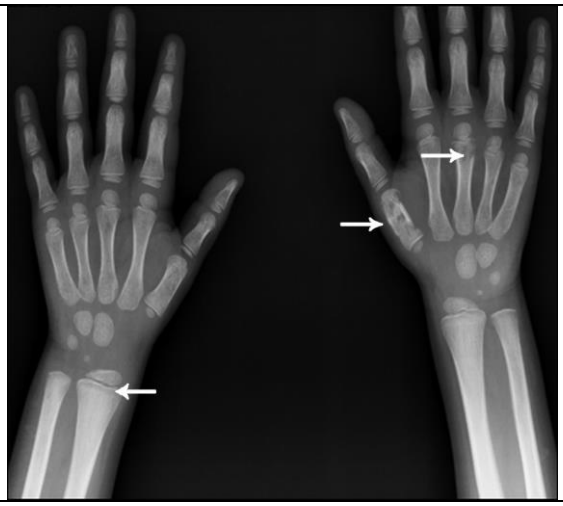
F- Leukemia

- Leukemia is the most common malignancy in childhood.
- Diagnosis is based on examination of peripheral blood smears and bone marrow biopsy

Radiographic Findings:

- Metaphyseal transverse translucent bands
  - Rapidly growing regions: Knee – Wrist – Ankle
- Metaphyseal cortical erosions
  - Medial side of proximal end of humerus and tibia
- Osteolytic lesion = Leukemic deposit
- Vertebral collapse
- Periosteal reaction

Metaphyseal transverse translucent bands	Periosteal reaction	Multiple osteolytic lesions + Generalized Osteopenia
		

Multiple collapsed vertebrae	
Metaphyseal cortical erosions at Medial side of proximal end of humerus	Metaphyseal transverse translucent bands + Osteolytic lesions
	

Role of MRI:

- To predict the stage of the disease in children with ALL without the need for unnecessary diagnostic bone marrow biopsies.
    - Although bone marrow aspiration and biopsy wilt still be needed to make a diagnosis specific for cell type.
- To evaluate the efficacy of treatment and to determine if the disease is in remission and to ensure that there has been no relapse of ALL.

MRI appearance of Acute Leukemia:

- T1 WI: Low SI (signal of VB lower than signal of disc)
- T2 / STIR: High SI
- Focal more commonly in myelocytic leukaemia
- Diffuse more commonly in lymphocytic leukaemia

Chronic Lymphocytic Leukemia	Acute Myeloid Leukemia

G- Langerhans Cell Histiocytosis

- A group of disorders caused by overproduction of histiocytes, a subtype of white blood cells
- Discovered by a student named Paul Langerhans in 1865 based on clinical observations
- The disease is commoner in the pediatric population

Tpes of Histiocytic disorders:

- Langerhans cell histiocytosis (LCH) is the most common
- Erdheim-Chester disease (ECD)
- Rosai-Dorfman disease (RDD)
- juvenile xanthogranuloma (JXG)
- Hemophagocytic lymphohistiocytosis (HLH).

3 Subtpes of LCH (old classification):

- Letterer-Siwe disease: disseminated fulminant disease, typically infants
- Hand-Schuller-Christian disease (HSC): chronic disseminated disease, children
- Eosinophilic Granuloma (EG)

3 Subtpes of LCH (New classification):

- **Unifocal (localized) form: (70% of LCH cases):**
  - Limited to a single bone or a few bones, and may involve the lung.
  - 5 and 15 years of age.
- **Multifocal unisystem (chronic recurring) form: (20% of LCH cases):**
  - Involves multiple bones
  - Reticuloendothelial system (ie, the liver, spleen, lymph nodes, and skin).
  - 1 and 5 years of age
- **Multifocal multisystem (fulminant) form: (10% of LCH cases) and often is fatal:**
  - It typically is diagnosed in the first 2 years of life
  - It is characterized by disseminated involvement of the reticuloendothelial system, anemia, and thrombocytopenia

System	Findings
Skull	"Punched-out" lesion, beveled edge (asymmetric destruction of inner and outer cortices), geographic skull (lesions grow, coalesce, and become maplike)
Spine	Vertebra plana (symmetric flattening of vertebral body)
Long bones	More commonly involved in children; diaphyseal or metaphyseal
Flat bones	"Floating teeth" if enough alveolar destruction; lytic lesion with sclerotic rim and surrounding areas of sclerosis more common in iliac bone
Liver	Hepatomegaly and solid or cystlike lesions
Lymph nodes	Most common in neck
CNS	Diabetes insipidus and neurodegeneration, absent posterior pituitary bright spot, thickening of pituitary stalk
Lung	Centrilobular nodules or cysts of varying sizes, with mid- to upper-lung distribution and sparing of costophrenic angles

1) Bone Lesions

- Bone lesions are the most common radiographic manifestation of LCH
- Occur in approximately 80% of patients

Location:

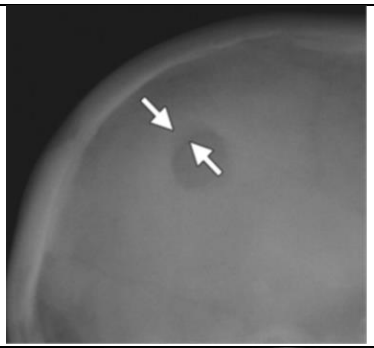
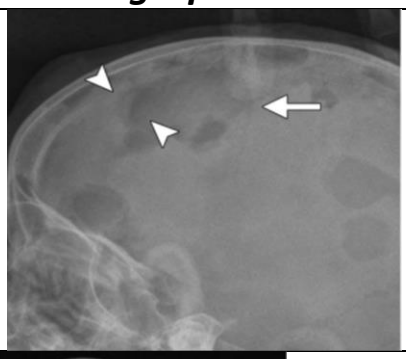
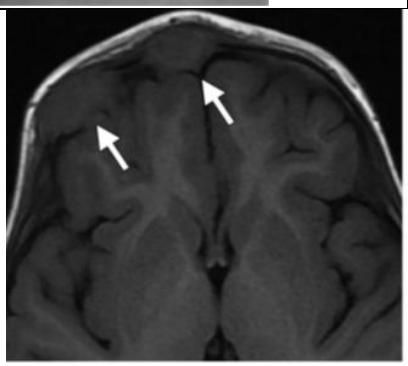
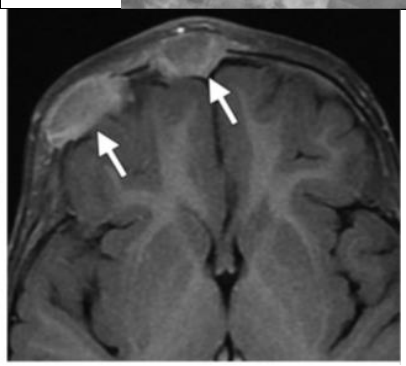
- The skull is the most common flat bone involved
- followed by the mandible, ribs, pelvis, and spine

i) Radiographic Pattern of Skull Lesions:

- Well-defined lytic lesions
- ***"Punched-out"*** appearance is caused by asymmetric destruction of the inner and outer cortices, which results in a characteristic ***beveled edge => Hole within hole sign***
- ***"Geographic skull":*** Skull lesions may grow in size and coalesce, creating a map-like appearance
- ***"Floating teeth"*** Destruction of the alveolar ridge
- ***Healing phase => Sclerotic margins***

MRI of the soft-tissue component

- T1: isointense
- T2: hyperintense
- +C: enhancement

"Punched-out"	*Geographic skull*
	
	

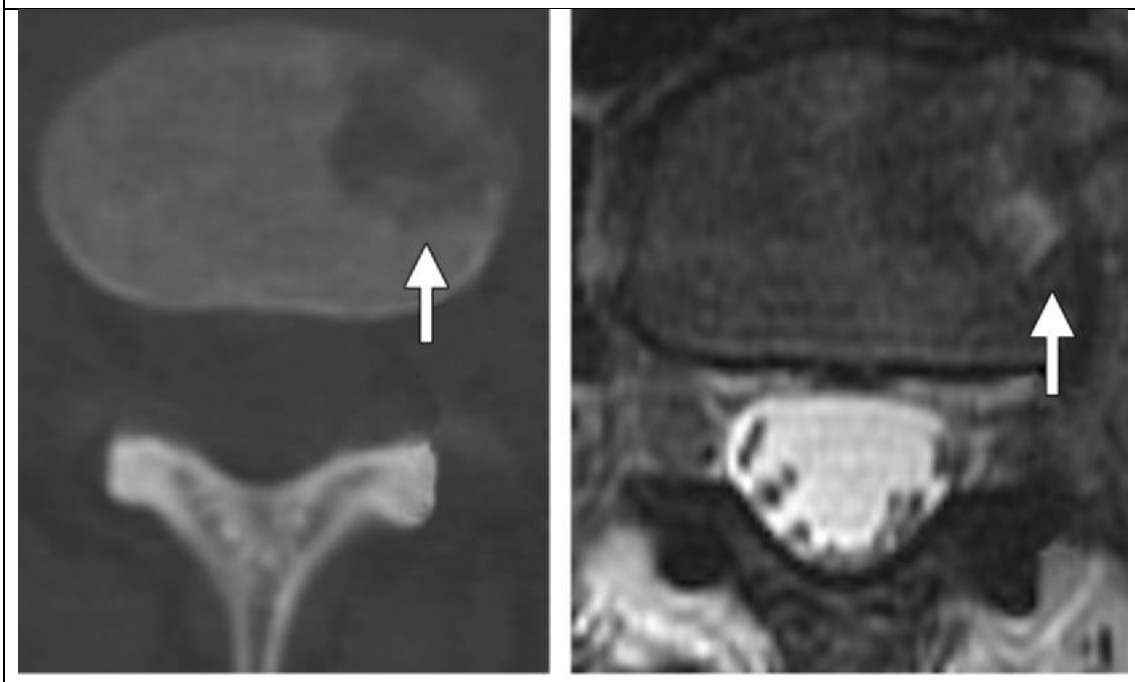
ii) Radiographic appearance of Spine:

Early => Lytic lesions

T1: Low signal

T2/STIR: High signal

+C: Contrast enhancement



a.

b.

c.

d.

Late => Vertebra plana = Vertebral symmetrical collapse

DD of Vertebra Plana in Children:

- LCH is most common cause of vertebra plana in children Leukemia
- Metastatic neuroblastoma
- Ewing sarcoma
- Osteogenesis imperfecta
- Trauma

iii) Radiographic appearance of Long bone Lesions:

- The femur, humerus, and tibia are the most commonly involved long bones
- Diaphysis or metaphysis
- Lytic, expansile, and aggressive
- MRI depict intramedullary lesions with extramedullary soft-tissue components
- T1: Low signal
- T2/STIR: High
- +C: Contrast enhancement.
- Bone scintigraphy: typically shows increased radiotracer uptake

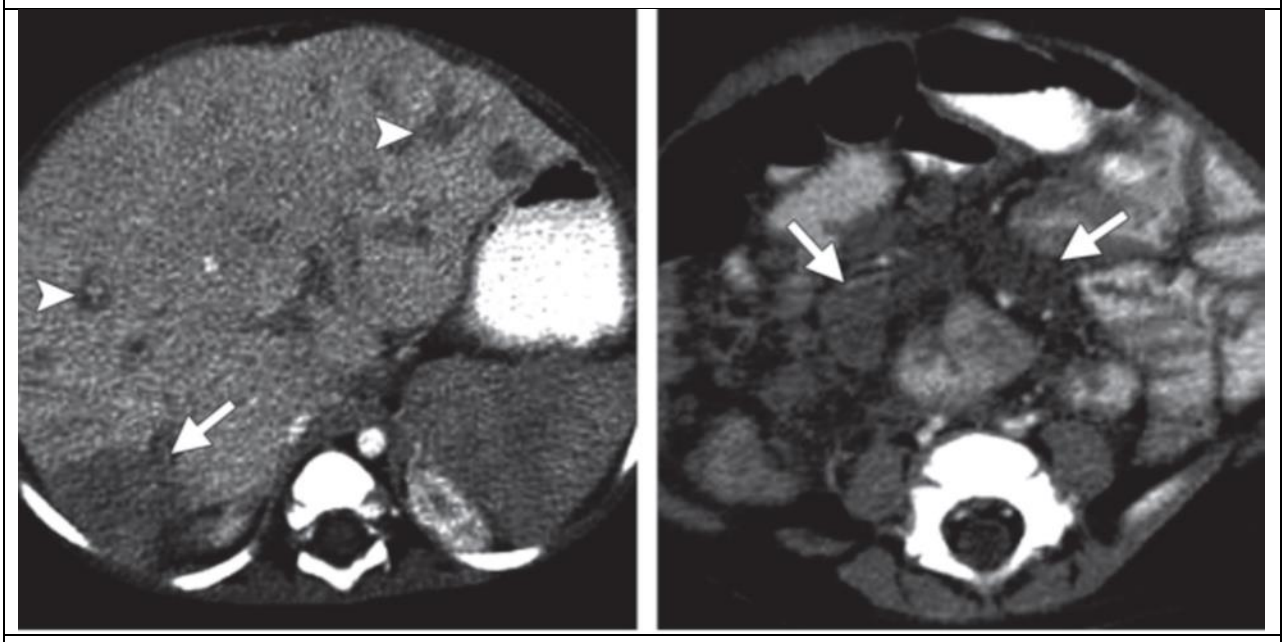
- As lesions become chronic, they resolve or appear sclerotic from periosteal new bone formation.
- A more mature lesion will typically have a sharply defined sclerotic margin

2) Reticuloendothelial System (Liver, Spleen, and Lymph Nodes)

- The liver is involved in approximately 15% of patients with LCH
  - is considered a “risk organ that indicates a worse prognosis
- The spleen is involved slightly less frequently than the liver
  - is considered a risk organ as well
- The lymph nodes are involved in approximately 20% of cases

Imaging findings:

- Hepatomegaly
- Splenomegaly
- Lymphadenopathy
- Focal solid lesions: Low CT attenuation
- Cyst like lesions
- Periportal fibrosis / edema: Periportal low attenuation
- Sclerosing cholangitis
- Liver failure

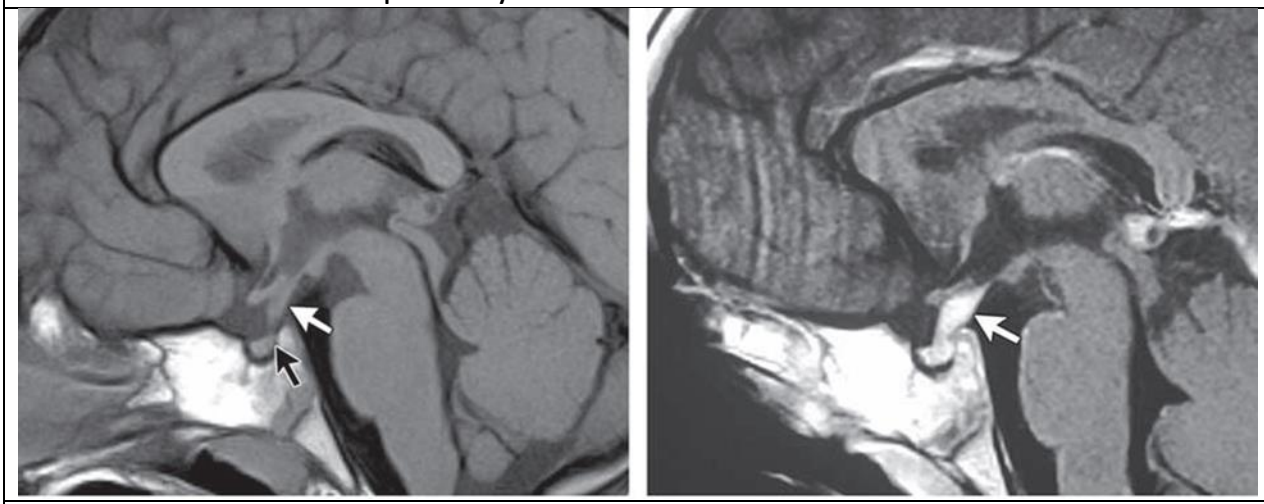


3) CNS Involvement

- CNS is involved in approximately 16% of LCH cases

i) Hypothalamic pituitary axis:

- The most common clinical CNS manifestation of LCH is diabetes insipidus secondary to infiltration of the posterior pituitary gland
- T1 demonstrates loss of the normal posterior pituitary bright spot
- Thickening of pituitary stalk >3 mm
- Enhancement of the pituitary stalk



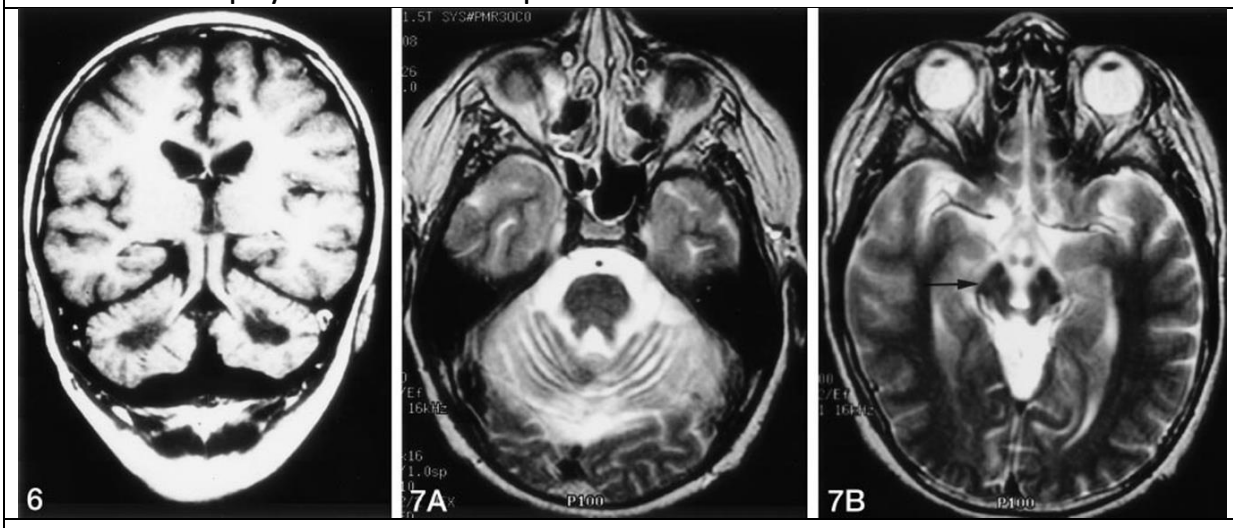
ii) Neurodegeneration Ataxia and cognitive dysfunction; lesions are predominantly in the cerebellum and basal ganglia

iii) White matter changes: Leukoencephalopathy like pattern: bilateral diffuse or patchy, usually symmetrical, involvement of the white matter without a clear vascular distribution; predominantly periventricular.

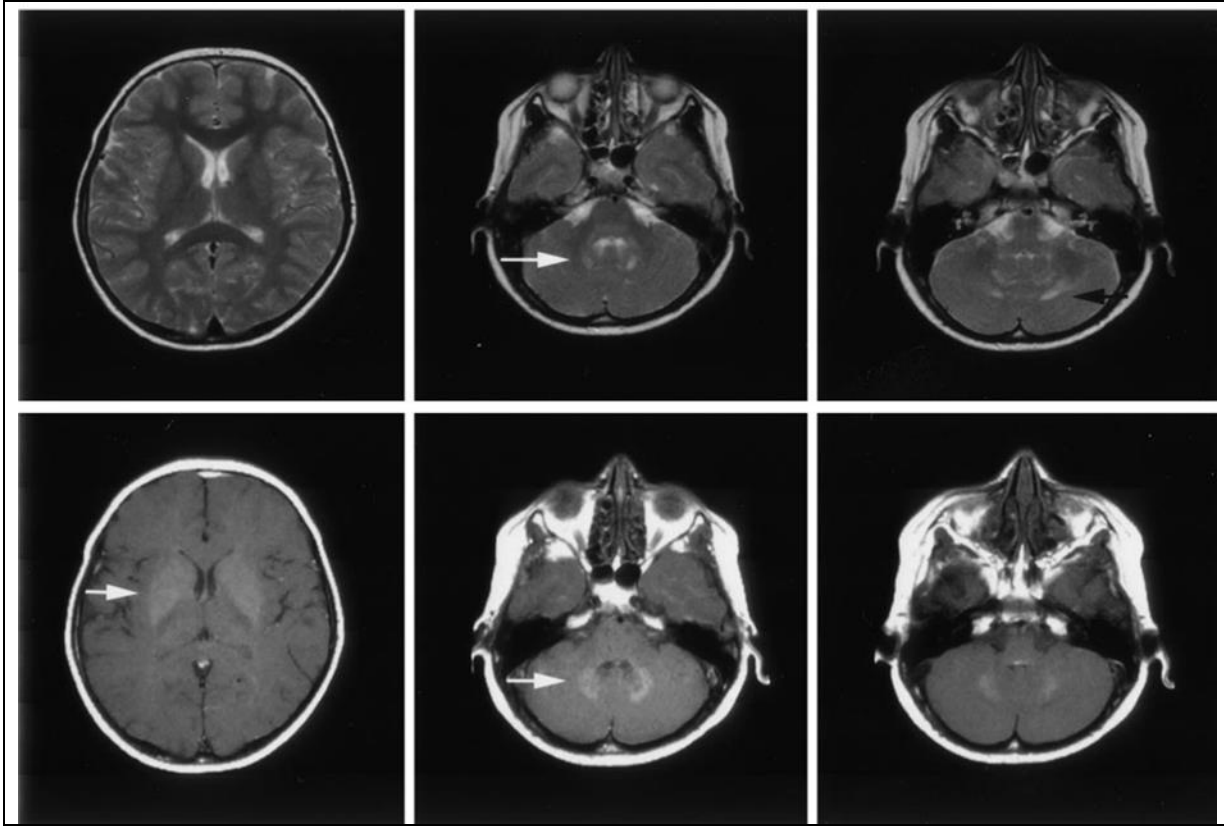
iv) Meningeal Lesions:

v) Choroid plexus involvement:

Neurodegeneration:
Cerebellar atrophy with thinned cerebellar peduncles
Midbrain atrophy with wide interpeduncular cistern



Abnormal signal in BG and dentate nuclei



4) Lung Involvement

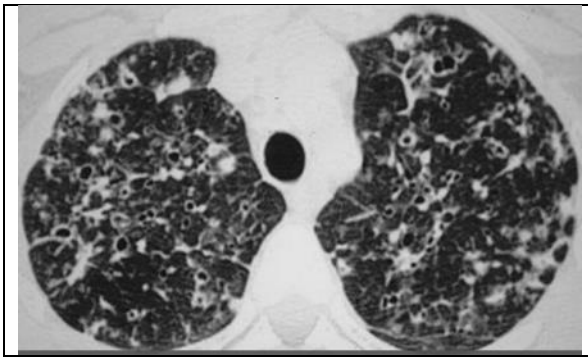
- Lung involvement occurs in approximately 10% of LCH cases
- It is much more common in ***adults***
- It is almost always associated with ***smoking***

Imaging findings:

- Centrilobular micronodules: Star fished shape
- Cysts: Bizarre shaped- vary in size but usually are less than 1 cm.
- A confluence of cysts may result in bullous formation
- Recurrent spontaneous pneumothorax

Distribution:

- Upper- to mid-lung distribution
- Sparing costophrenic angles
- Sparing lung bases



5) Cutaneous Lesions

Location

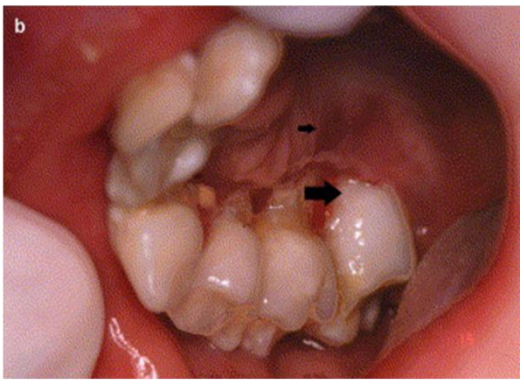
- Perineum, Retro auricular, Temporal, Trunk, Oral

Nature

- Purpuric, Seborrheic , Erythematous papules, Nodular ulcerative

Commonest presentation in Neonates and infants

- 86 % in multisystem and 90 % in single system
- 40 % may progress to develop multisystem disease.



H- Non-LCH Histiocytic Disorders

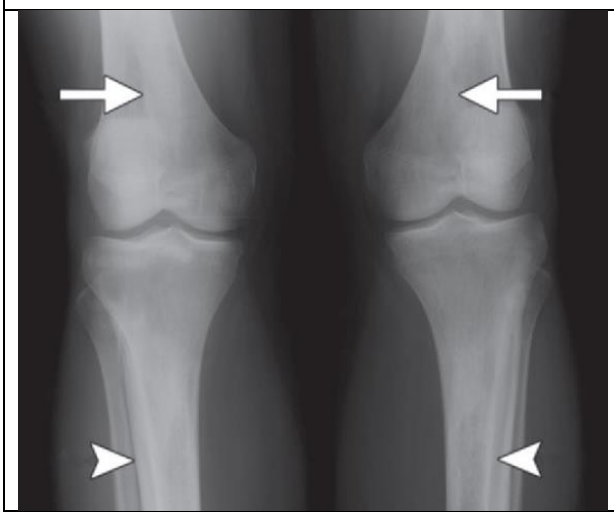
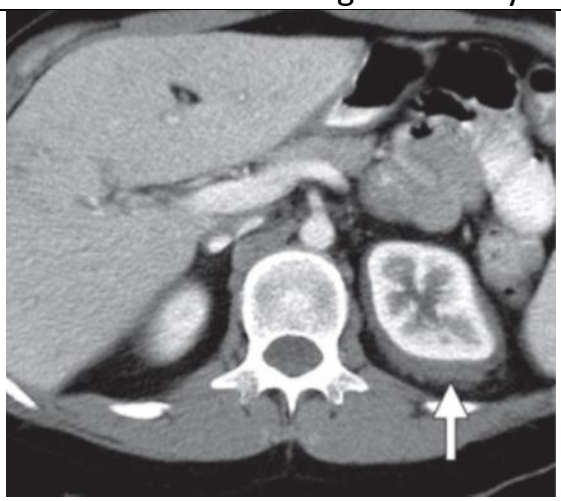
- Non-LCH histiocytic disorders are far less common than LCH and include:
  - ECD, JXG, RDD, and HLH.

Tpes of Histiocytic disorders:

- Langerhans cell histiocytosis (LCH) is the most common
- Erdheim-Chester disease (ECD)
- Juvenile Xanthogranuloma (JXG)
- Rosai-Dorfman disease (RDD)
- Hemophagocytic lymphohistiocytosis (HLH).

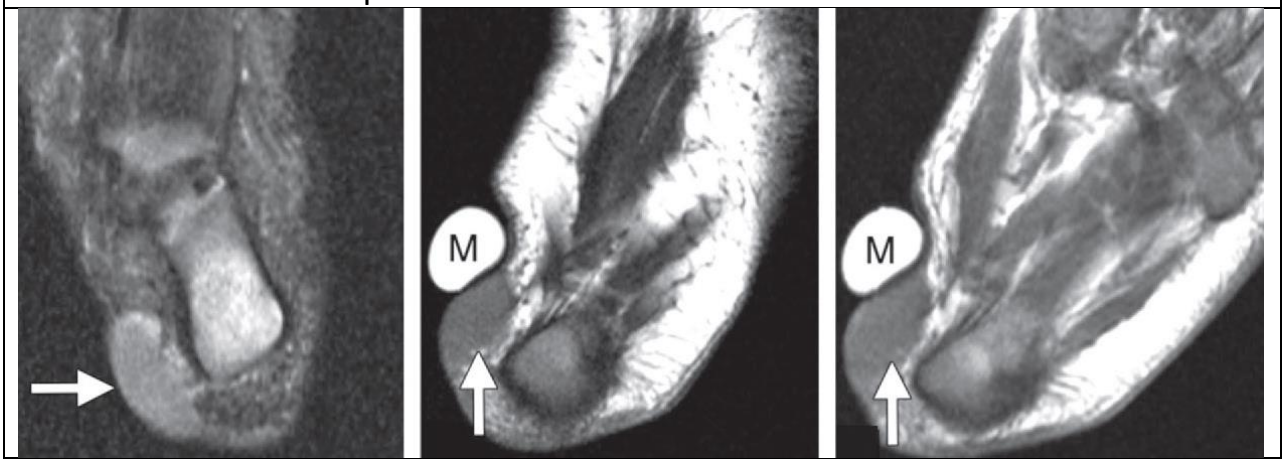
Disease	Most Common Age Group	Manifestations	Pitfalls	Prognosis
ECD	Adults	Bilateral and symmetrical osteosclerosis (most common in long bones) Homogeneous rind of tissue surrounding kidneys Diabetes insipidus Sella and orbits are common sites of involvement	. . .	Variable
RDD	Children and young adults	Painless neck lymphadenopathy CNS lesions in the epidural and subdural compartments of the skull base are common	CNS lesion commonly mimics meningioma Bone involvement can mimic LCH and metastatic disease	Overall good
HLH	Infants and young children	US: hepatomegaly, splenomegaly, gallbladder wall thickening CNS: periventricular white matter signal abnormalities and cerebral volume loss	Difficult to diagnose, many nonspecific findings	Variable
JXG	Infants and young children	Dermal manifestations most common; diagnosis usually made clinically	...	Relatively benign disorder

Erdheim-Chester disease (ECD)

Patchy osteosclerosis of long bones	homogeneously hypoenhancing rind of soft tissue surrounding the kidneys
	

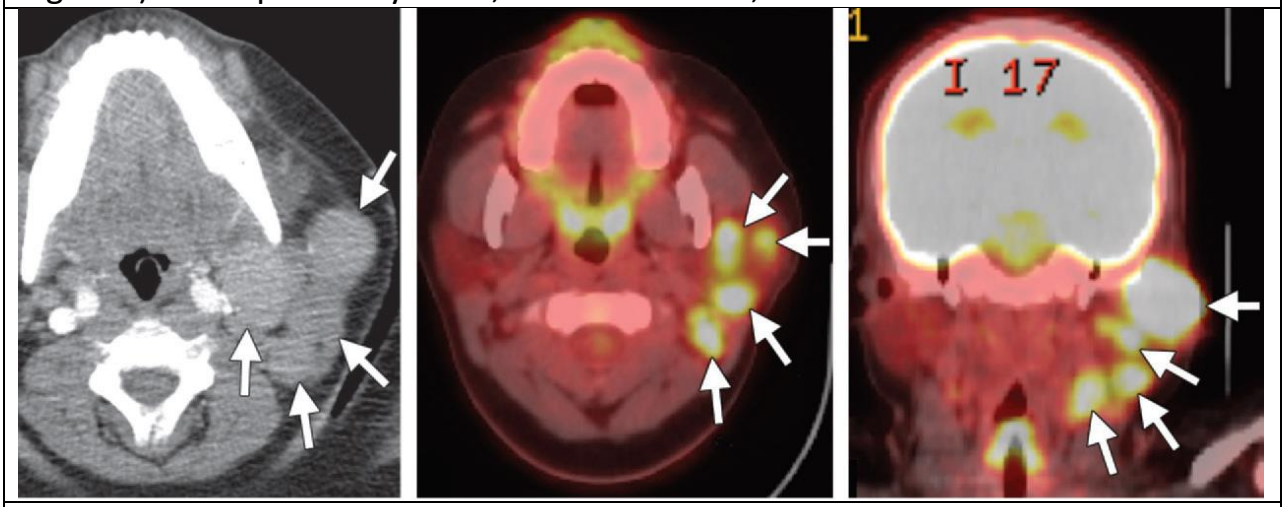
Juvenile xanthogranuloma (JXG)

The most common manifestations are dermal; patients present with a small yellow-reddish papule, plaque, or nodule early in the disease process. Subcutaneous and deep soft tissue lesions.

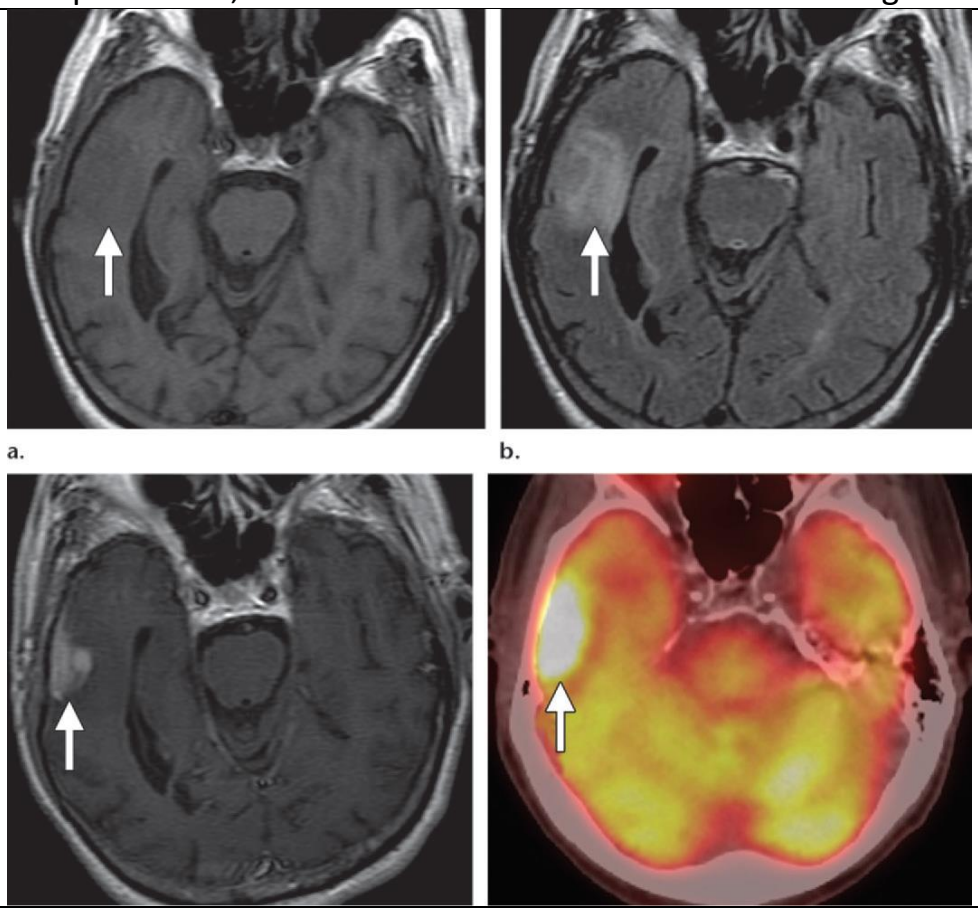


Rosai-Dorfman Disease (RDD)

The most common manifestation of RDD is nonspecific painless lymphadenopathy (most often cervical and less commonly retroperitoneal, mediastinal, axillary, or inguinal) accompanied by fever, an elevated ESR, and mild anemia.

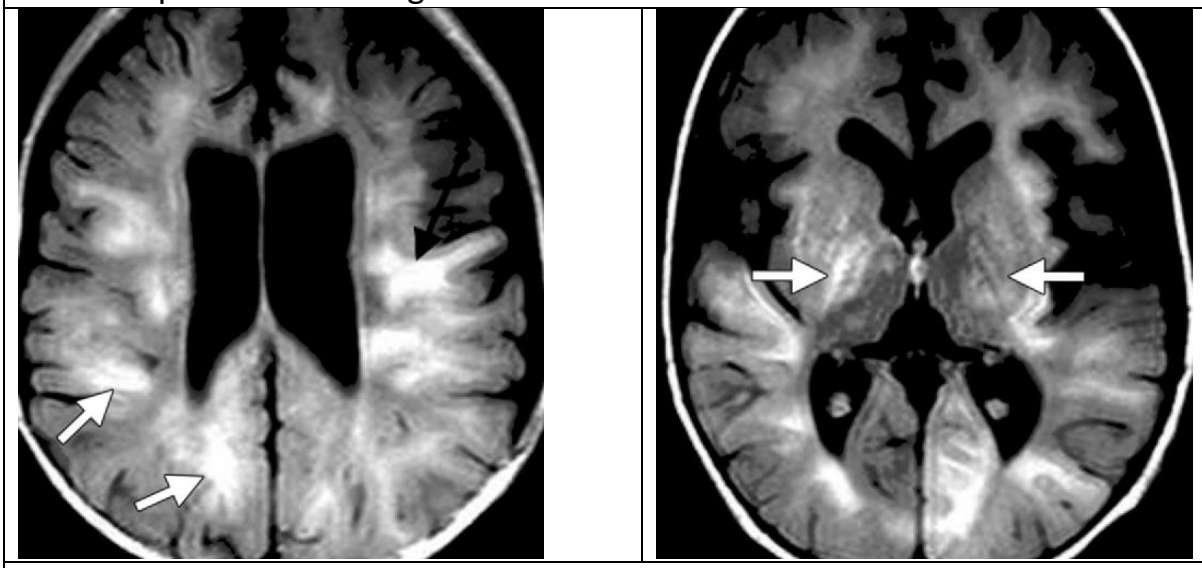


CNS manifestations include intracranial lesions primarily in the epidural or subdural compartments; these lesions can be confused with meningiomas

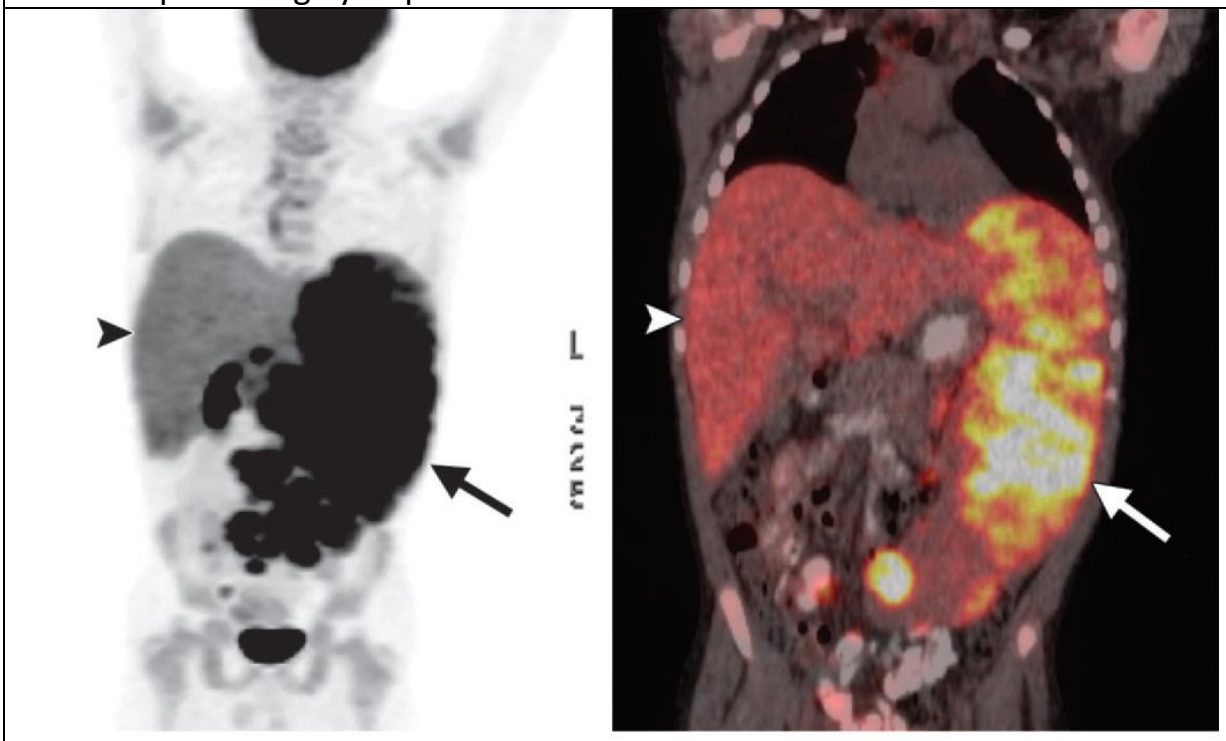


Hemophagocytic lymphohistiocytosis (HLH).

CNS: Deep WM abonral signal + Volume loss



Marked splenomegaly + splenic infiltration.



I- Gaucher Disease

- GAUCHER disease is a lipid storage disease.

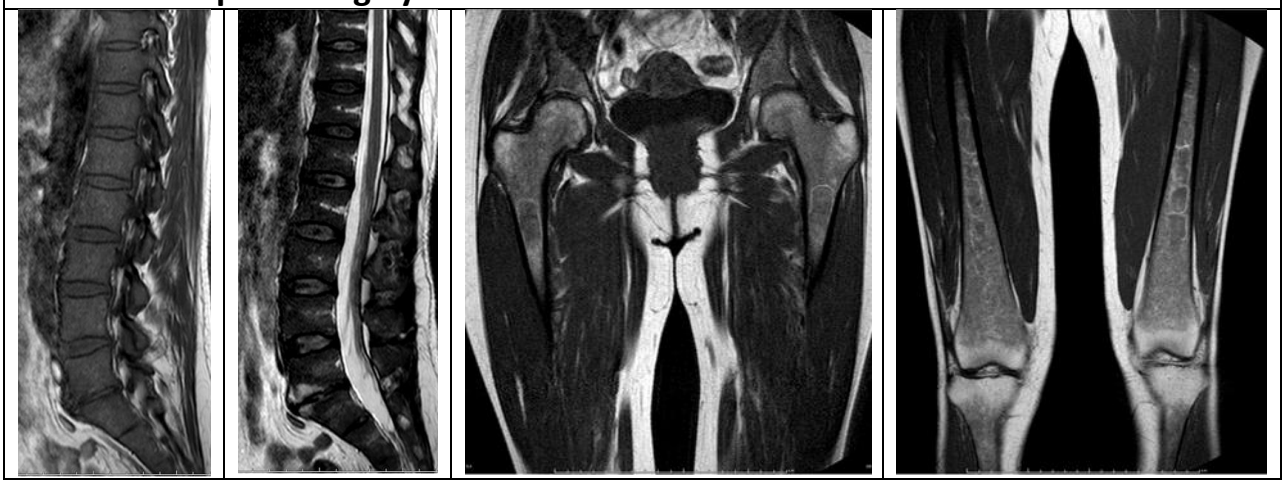
Pathophysiology:

- The cause of the disorder was found to be deficient activity of the enzyme glucocerebrosidase, which catalyzes the hydrolysis of glucocerebroside to its breakdown products of ceramide and glucose.
- Glucocerebroside accumulates in the reticuloendothelial cells (macrophages) of the bone marmow, spleen, and liver.
- Accumulation of unmetabolized glucocemebmoside in bone marrow macrophages leads to replacement of the hematopoietic tissue, as welt as to frequent fractures, episodic bone pain, osteopenia, and osteonecrosis.
- Accumulation of unmetabolized glucocemebmoside in the spleen and liver leads to hepatosplenomegaly, resulting in the premature destruction of blood cells

Muscloskeletal Manifestions

- Long bones are most severely affected
- Reduced T1 and T2 bone marrow signal (due to infiltration of gaucher cells)
- Quantitative chemical shift imaging (QCSI)= Measurement of marrow fat fraction: lower fat fractions in patients with Gaucher disease
- Metaphyseal notching of humeri
- Pathological fractures
- Erlenmeyer flask deformity
- **Features of superimposed osteonecrosis**
- **H-shaped deformity**

- **Hepatomegaly**
- **Massive splenomegaly**



J- Multiple Myeloma

- is a malignant plasma cell disorder that usually affects the bone marrow.
- Most common primary bone tumor
- 10% of hematologic malignancies.
- Ages : 40 – 80y
- Sex: M > F

Aetiology:

- The cause of MM is unknown.
- Radiation exposure increases the risk, as evidenced by a higher than expected rate of disease in:
    - Atomic bomb survivors
    - Radiation workers
    - Post-irradiated patients with ankylosing spondylitis.

Clinical Picture:

- Bone pain
- Anaemia
- Renal failure/proteinuria

Laboratory Diagnosis::

- Detection in blood and/or urine of a monoclonal protein (M protein) produced by the abnormal plasma cells.
    - IgA &/or IgG peak (monoclonal gammopathy) by electrophoresis
    - Bence Jones protein in urine
    - Revered albumin/globulin ratio
- Nonselective iliac crest bone marrow biopsy: percentage of plasma cells in aspirate.

Durie and Salmon Plus System for Staging of Multiple Myeloma

Stage*	Laboratory Findings†	Imaging Findings‡
IA§	≥10% plasma cells	Limited disease or plasmacytoma
IB	≥10% plasma cells, end organ damage	Mild diffuse disease, <5 focal lesions,
IIA, IIB	≥10% plasma cells, end organ damage	Moderate diffuse disease, 5–20 focal lesions
IIIA, IIIB	≥10% plasma cells, end organ damage	Severe diffuse disease, >20 focal lesions

2 Types

1) **Multiple Myeloma => Axial Skeleton:**
    - Vertebrae (66%)
    - Ribs (45%)
    - Skull (40%)
    - Shoulder (40%)
    - Pelvis (30%)
    - Long bones (25%)
2) **Solitary Plasmacytoma:**
    - Vertebral body – Pelvis – Femur

❖ **Radiographic findings:**

- **Multiple well defined lytic lesions: punched out lesions**
- **Generalized osteopenia**
- **Vertebral collapse.**
- **Pathological fracture**

Post-Treatment Follow up:

A skeletal survey should be repeated following completion of treatment:

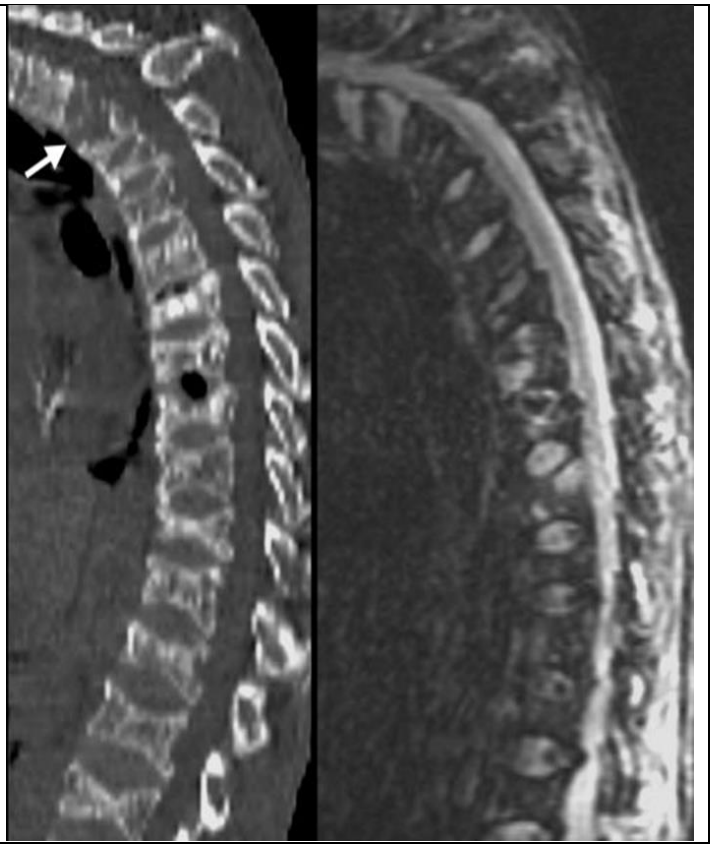
- Shrinkage or sclerosing lesions indicate partial or complete resolution.
- New or enlarging lesions indicate progressive disease.

❖ **Bone Scan:**

- Inferior to skeletal radiographs in evaluating MM
- Normal or cold > hot

❖ **Role of CT:**

- To evaluate for the presence or absence of bony lesions.
- Aid in performing biopsy.
- To demonstrate disseminated disease in a patient with an apparently solitary plasmacytoma



❖ Role of MRI:

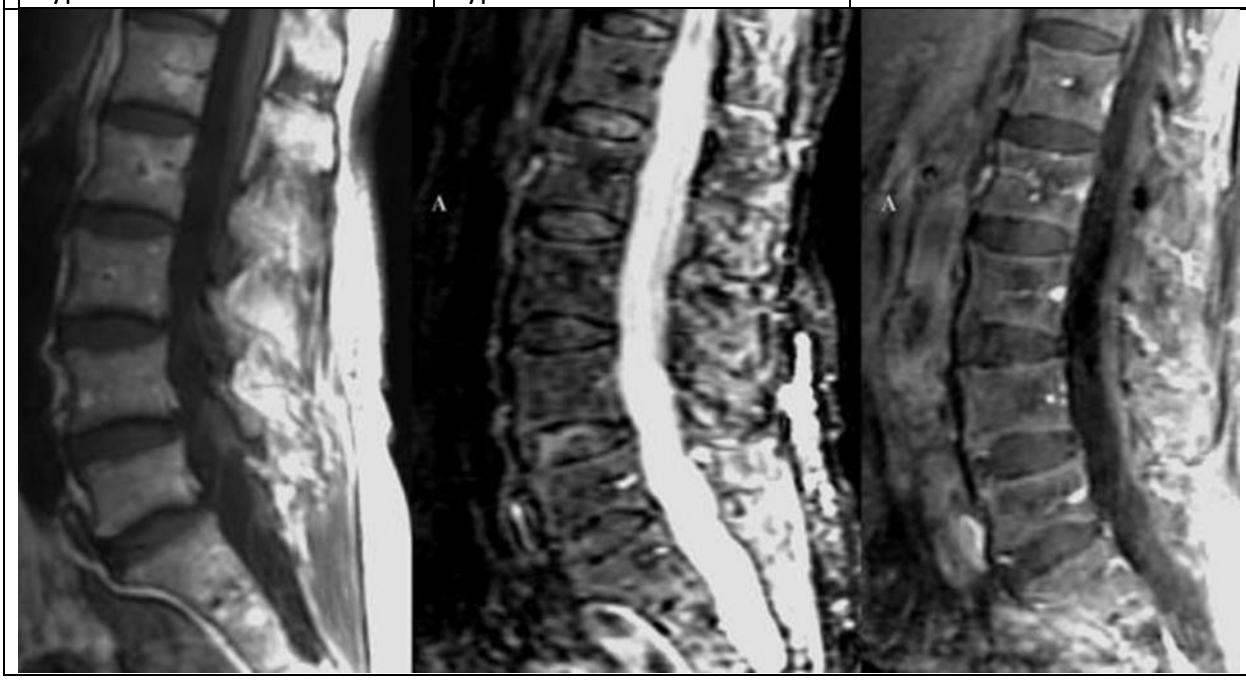
- Allow the acquisition of survey studies of long segments of the axial skeleton within a reasonable time period.
- Determine the exact location, size, and local compressive effects of the focal plasmacytomas.
- Depicting vertebral compression fractures and assessing spinal cord compression.
- MR images help define response to treatment.

5 Patterns of BM infiltration:

- **MRI may be normal**
- **Focal (Multifocal) lesions**
- **"Salt and pepper" = Micronodular**
- **Diffuse homogenous**
- **Diffuse heterogeneous**

i) Normal BM:

T1WI: Diffuse homogenous hyperintense	STIR: Diffuse homogenous hypointense	T1+C FS: no marrow enhancement



ii) Diffuse Homogenous BM Infiltration

T1 WI: Diffuse hypointense	STIR: Diffuse hyperintense	T1+C: Marked enhancement

iii) Diffuse Heterogeneous BM Infiltration

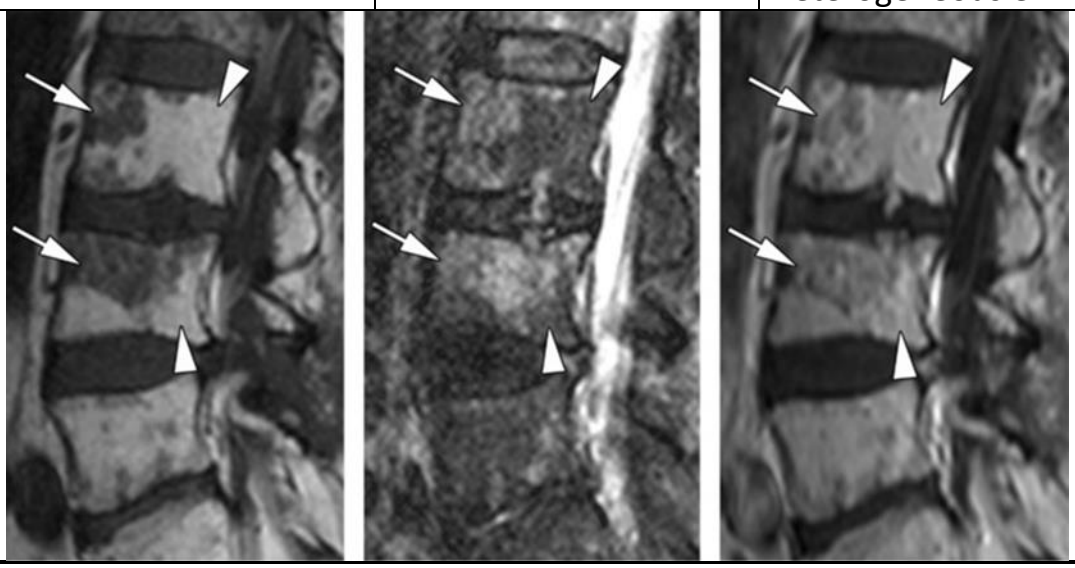
Mixed areas of hypointensity and hyperintensity on T1 WI, STIR, and +C images.

iv) Salt-and-pepper pattern:

T1: Micronodular foci of low signal	STIR: Microndular foci of high signal	+C: Micronodular enhancing foci

v) Focal (Multifocal) lesions

T1: Multifocal patchy areas of Low signal	STIR: Multifocal patchy areas of high signal	+C: Multifocal patchy areas of heterogeneous enh



MRI Imaging Appearance of Normal Fatty BM:

T1: High signal
T2: High signal
STIR: Loss of high signal
+C: No Enhancement

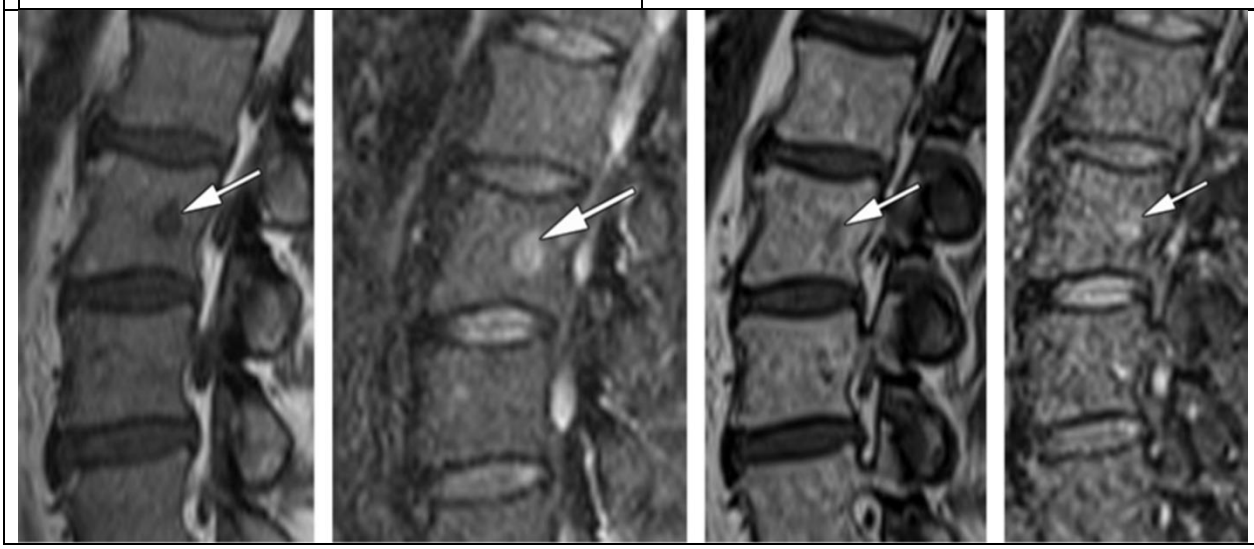
MRI Imaging Appearance of Active Multiple Myeloma:

T1: Low signal
T2/STIR: High signal
+C: homogenous contrast enhancement

Posttreatment MRI Imaging appearance:

- Decrease or disappearance of the focal lesions or diffuse disease
- Conversion of diffuse to focal or variegated pattern
- T1: gradual replacement of infiltrated marrow, first by red marrow and later by fatty marrow
- T2: lesions remain hyperintense even in good and partial responders. This has been related to necrotic changes
- +C: Rim or No enhancement.

Pre-Treatment	Post-Treatment



❖ Role of PETCT:

- FDG PET/CT is an important tool for staging and prognosis in multiple myeloma because of its ability to depict metabolic activity, extramedullary disease, and secondary lesions that are not attributable to multiple myeloma.
- FDG PET/CT is most valuable for evaluating the disease burden in nonsecretory multiple myeloma.
- FDG PET/CT may be useful for monitoring multiple myeloma after treatment.
    - ⇨ Decreased FDG uptake representing decreased bone marrow activity is seen in focal multiple myeloma lesions after successful treatment.

Multiple foci of intra- and extramedullary metabolic activity	Pre-treatment	Post-treatment

❖ PLASMACYTOMA

A solitary bone plasmacytoma (SBP) may involve any bone, but it has a predisposition for the red marrow - containing axial skeleton.
Age: 4th to 6th decades
Sex: M > F

Imaging Findings:

Solitary expansile lytic lesion
Thinning and destruction of cortex
Bubbly/trabeculated appearance
'Mini-brain' appearance = curvilinear low signal areas within lesion
'Soap-bubble' appearance = multicystic purely lytic lesion
T1 : hypo- to isointense
T2 : iso- to hyperintense to muscle
T1 C+ : variable enhancement

Difference between multiple myeloma and Metastases

Multiple myeloma	Metastases
Vertebral pedicles and posterior elements less commonly involved	Vertebral pedicles and posterior elements commonly involved
Soft tissue mass is associated with a bony lesion	Soft tissue mass is relatively uncommon
Mandible may be involved	Mandible rarely involved
Radionuclide studies may give false negative result	Radionuclide studies are very sensitive
Serum alkaline phosphate may be normal	Serum alkaline phosphate always raised
Lesions of uniform size	Small and large lesions

Comparison of Multiple myeloma and lymphoma

Feature	MM	HL	NHL
Age	After 40 years	Any age, M/c in young adults	20-50 years
sites	M/c is Spine other sites are pelvis, skull, ribs, scapula	M/c is spine, thoracic cage and pelvis	Diaphysis of long bones. Femur is M/c site then humerus. Most cases occur near knee
Occurrence	Primary bone disease	Very rare primary bone disease	Rare but more common than HL
Types of lesions	Mostly lytic and of same type	Mostly mixed, 1/3rd lytic, rest are sclerotic	Permeative or moth eaten or lytic. Multiple lesions are of same type

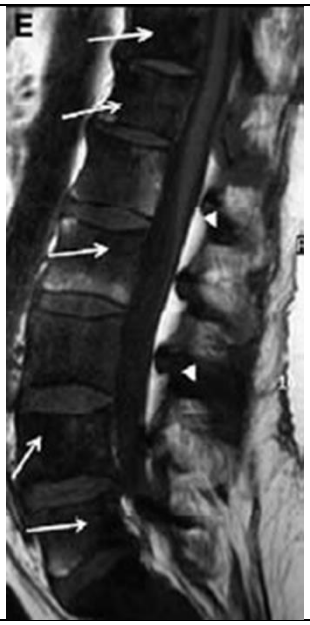
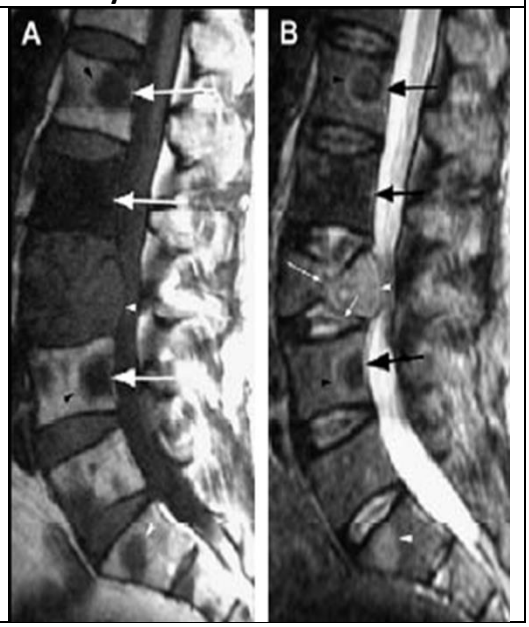
K- Metastasis

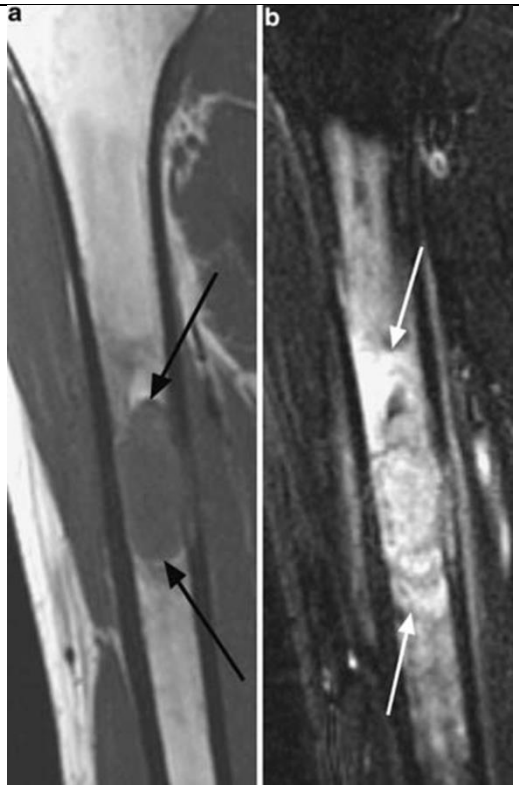
- Metastatic cancer to skeletal bone occurs in 30-70% of all cancer patients
- The skeletal system is the most common site of involvement by metastatic disease, after the lungs and the liver.
- Lesions generally arise in descending order of frequency, from primary malignancies in the breast, lung, prostate, kidney and Thyroid.
- In children, Neuroblastoma, is one of the most common malignancies accounting for 8-10% of all childhood cancer.

Location and Distribution:

- 90% of metastatic lesions are found in the distribution of the red marrow in adults.
    - Vertebrae (69%)
    - Pelvis (41%),
    - Proximal femora (25%)
    - Skull (14%).
- Extremity is much less commonly involved (10-15%).

Osteolytic Metastasis	Osteoblastic Metastasis
Bronchogenic	Prostate carcinoma
Breast	Breast cancer
Thyroid	Lymphoma
kidney	carcinoid tumors
Colon	Mucinous adenocarcinoma
Neuroblastoma (in childhood)	Pancreatic adenocarcinoma
	Bladder carcinoma
	Neuroblastoma

Lytic Metastasis	Sclerotic Metastasis	Mixed lytic & sclerotic metastases
		

Diffuse BM Metastatic infiltration	Destructive Metastatic lesion
	

Paget Disease =

Osteitis Deformans

- chronic metabolic disorder of abnormal bone remodeling in adult skeleton, in which there is overactive osteoclasts and osteoblasts

- Paget disease is the second most common bone disease after osteoporosis that affects elderly persons

- Sex: Males > females.
- Age > 55 y.

Clinical presentation

- The majority (approximately three-quarters) of patients are asymptomatic at the time of diagnosis.
- Localized pain and tenderness
- Increased focal temperature due to hyperaemia (due to hypervascularity)
- Increased bone size: historically changing hat size was a giveaway
- Bowing deformities
- Kyphosis of the spine
- Decreased range of motion

Markers

- Elevated serum alkaline phosphatase (ALP)
- Normal calcium and phosphorous levels
- Increased urine hydroxyproline

Distribution => Polystotic & Asymmetrical:

- Pelvis (30%–75%)
- Spine (30%–75%)
- Skull (25%–65%)
- Proximal long bones (25%–30%)

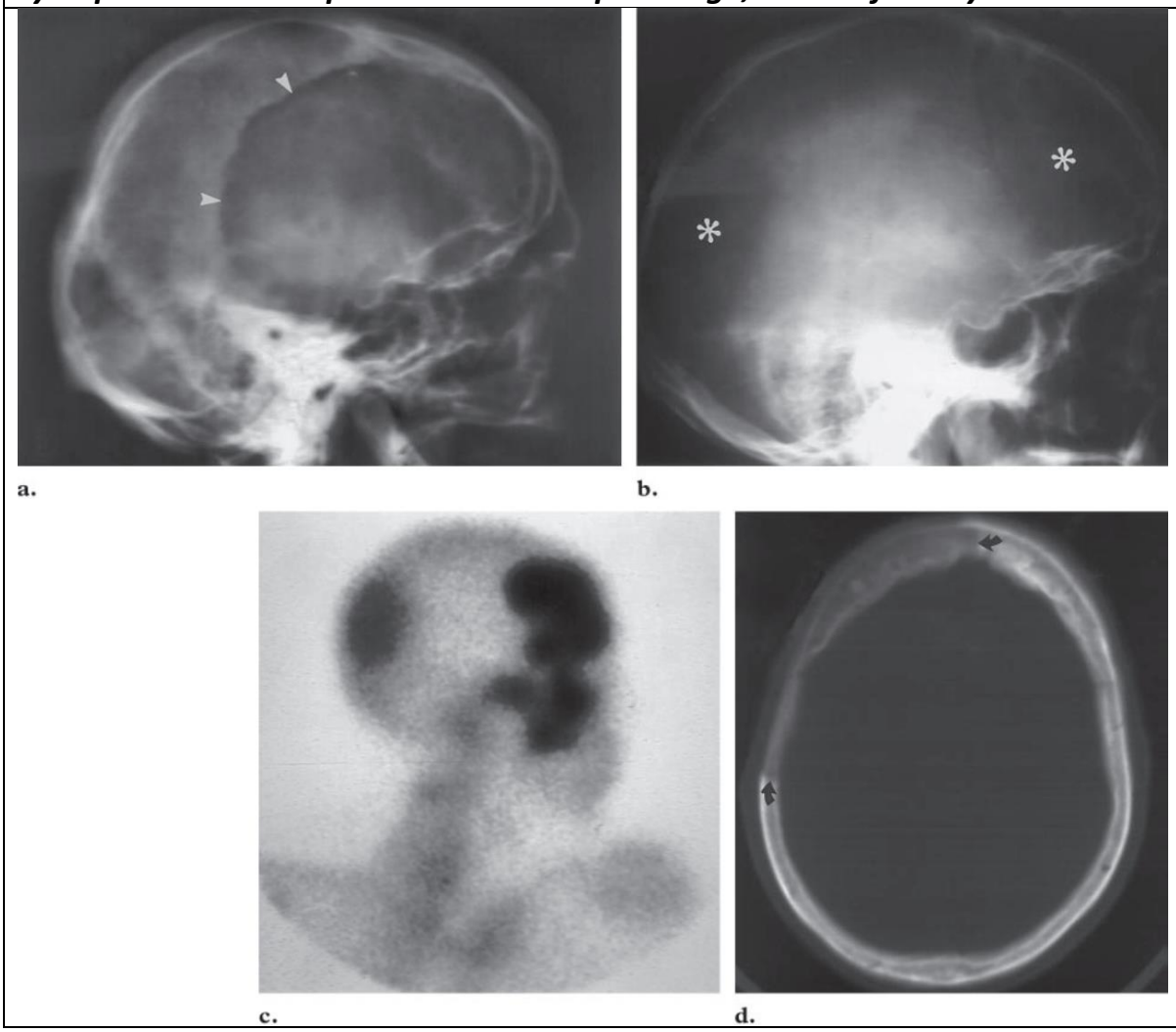
3 Phases:

- Lytic phase = Active stage; predominated by osteoclastic activity
- Mixed (active): osteoblastic as well as osteoclastic activity
- Sclerotic phase = Inactive phase = Quiescent phase

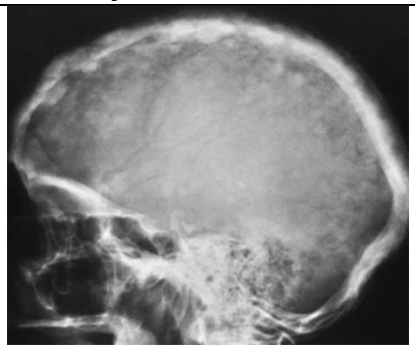
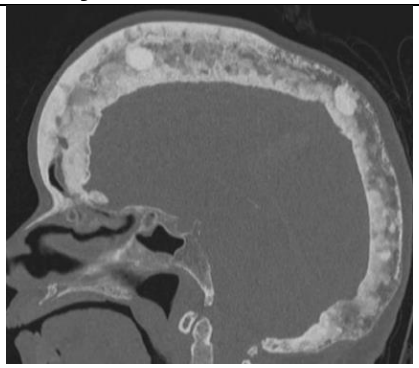
❖ Skull

- Osteoporosis circumscripta: large, well-defined lytic lesion
- Cotton wool appearance: mixed lytic and sclerotic lesions of the skull
- Diploic widening: both inner and outer calvarial tables are involved, with the former usually more extensively affected
- Base of skull: Cortical thickening, sclerosis and flattening
- Narrowing of neural foramina: hearing loss – facial palsy – blindness.
- Basilar invagination + Narrowing of foramen magnum => Cord compression.
- Tam o'Shanter sign: frontal bone enlargement, with the appearance of the skull falling over the facial bones, like a Tam o'Shanter hat

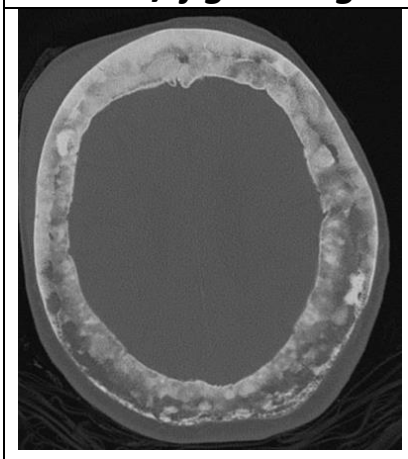
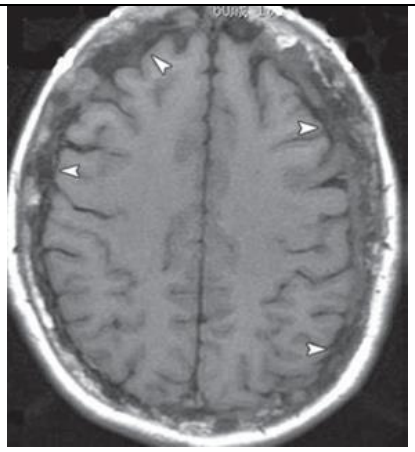
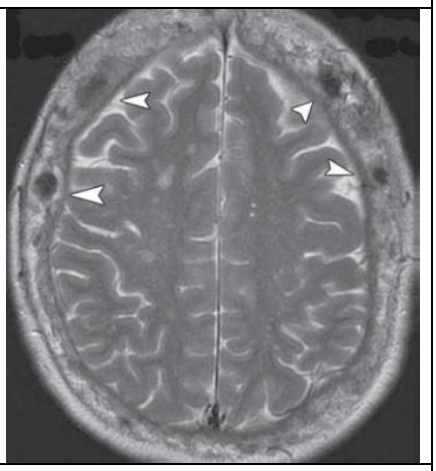
Lytic phase => Osteoporosis circumscripta: large, well-defined lytic lesion



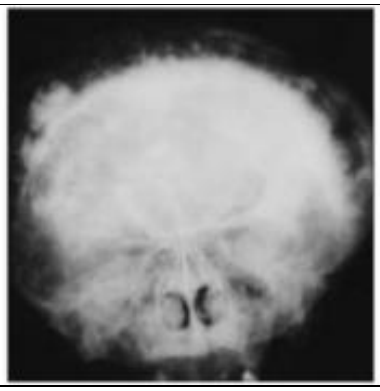
Cotton wool appearance: Mixed lytic and sclerotic lesions of the skull

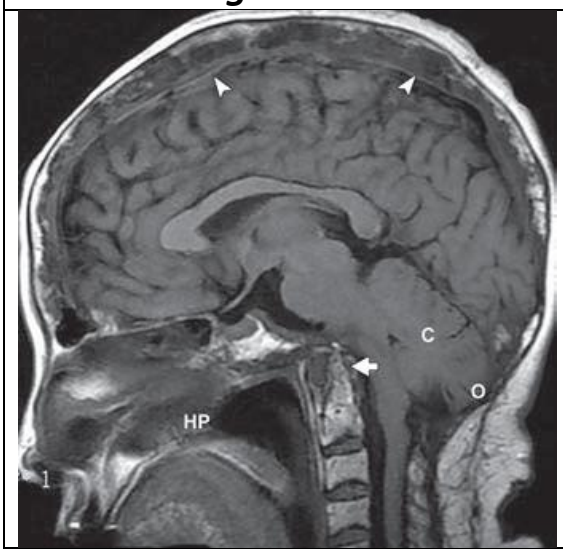
Mosaic / jigsaw sign

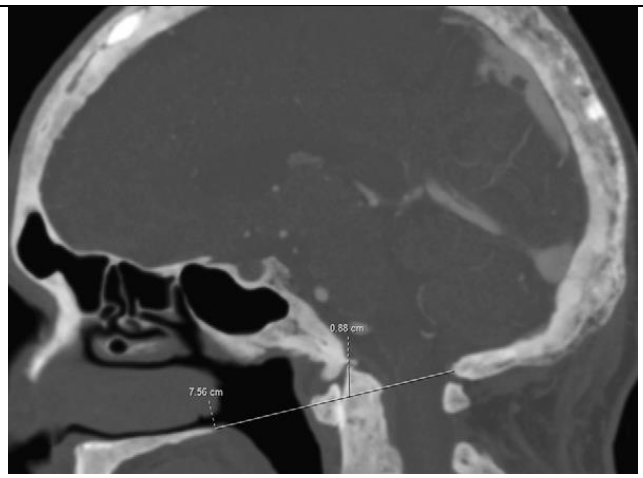




Tam O'Shanter" sign



Basilar Invagination



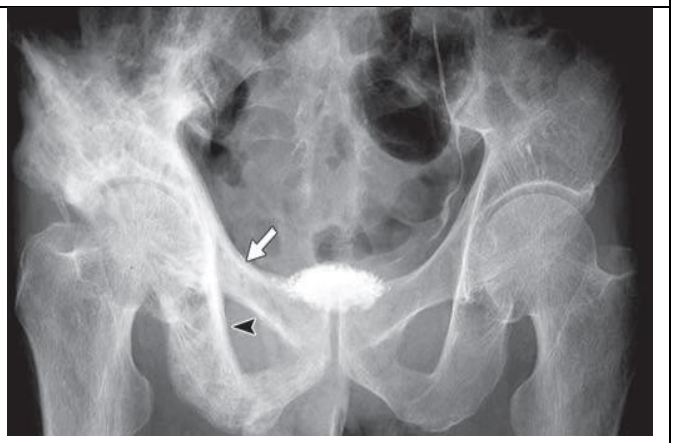


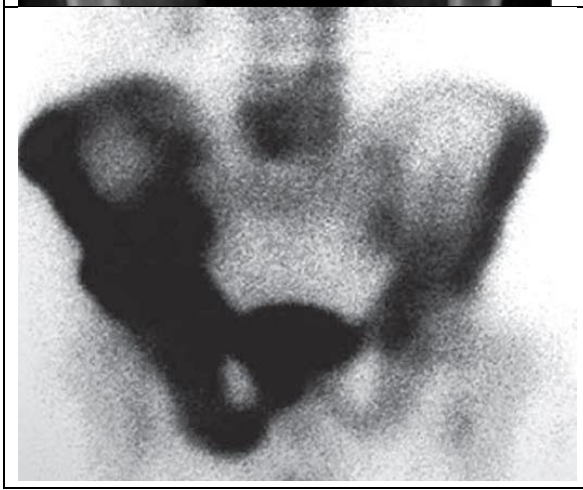
Bone thickening and heterogeneity of the facial bones

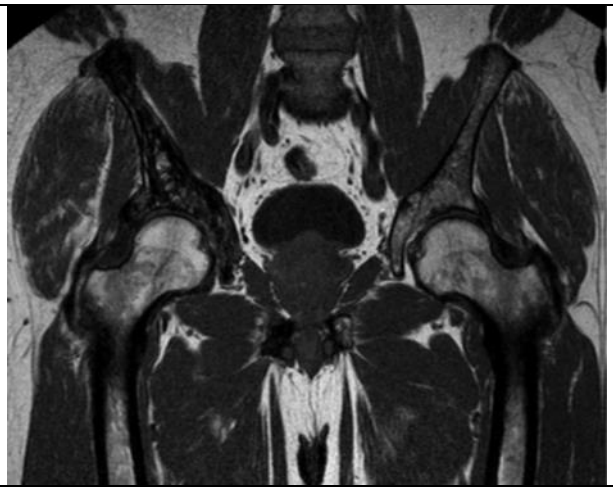
Bone thickening and heterogeneity of the temporal bones

❖ Pelvis

- Thickening of iliopubic and ilioischial lines
- Thickening of trabeculaions
- Pelvic brim sign
- Patchy areas of sclerosis with lucent defects
- May see obliteration of Kohler's teardrop
- Protrusio acetabuli







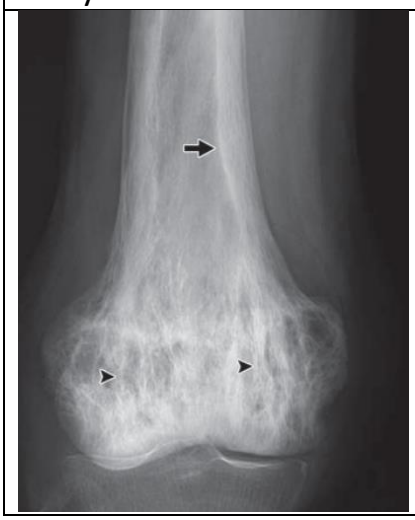
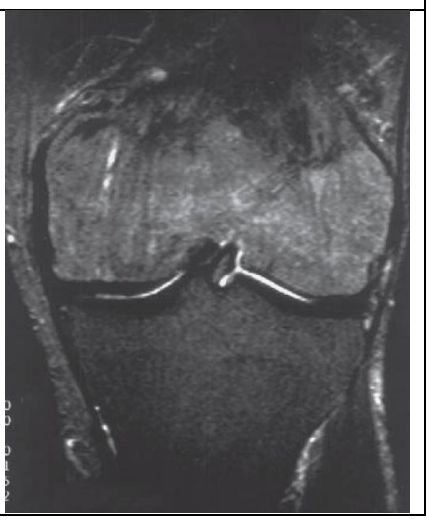
❖ Long bones:

- Thickening of cortex
- Enlargement of bone
- Bowing of bone

Blade of grass sign = Candle flame sign:

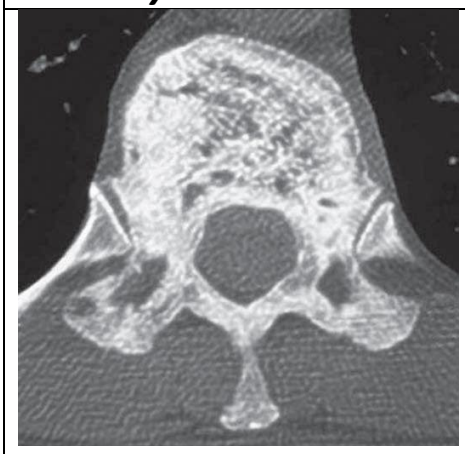
V-shped corticsl lytic lesion and advnces along the shaft

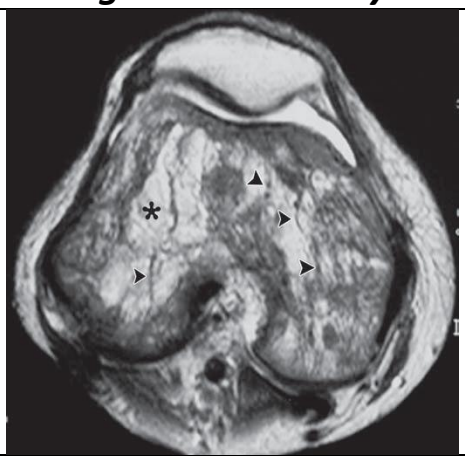
Cross-hatched pattern (arrowheads): mixed lytic and sclerotic start in subarticular location + Trabecular thickening + Cortical thickening (arrow).

X-ray	Coronal T1	Coronal STIR
		

❖ Spine

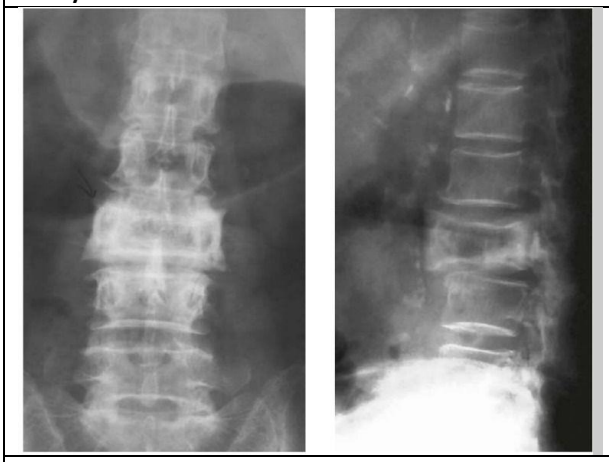
Mixed lytic and sclerotic changes involving vertebral body and arch.



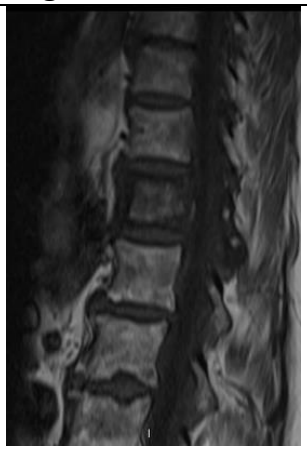


Picture-frame Vertebrae: coarse and sclerotic peripheral trabecular pattern and central osteopenia.

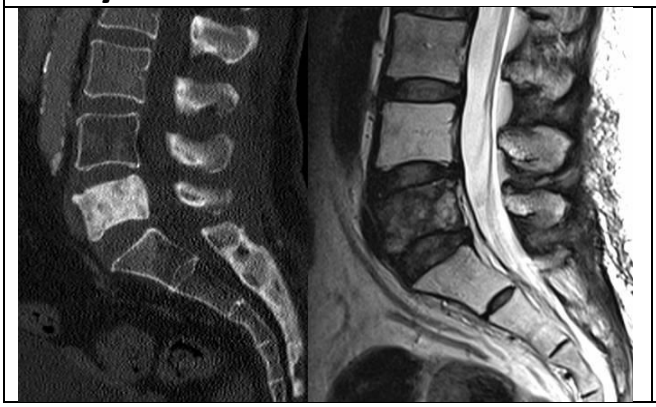
Xray

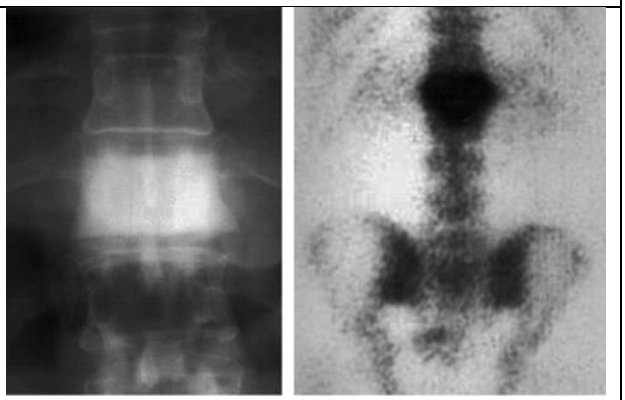


Sagittal T1



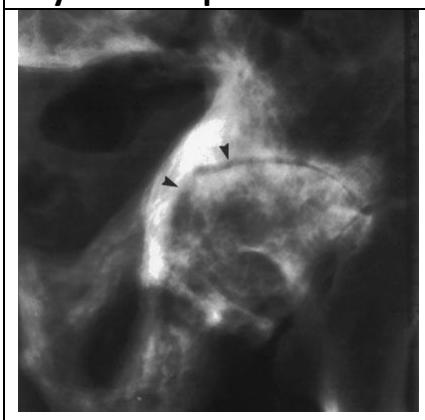
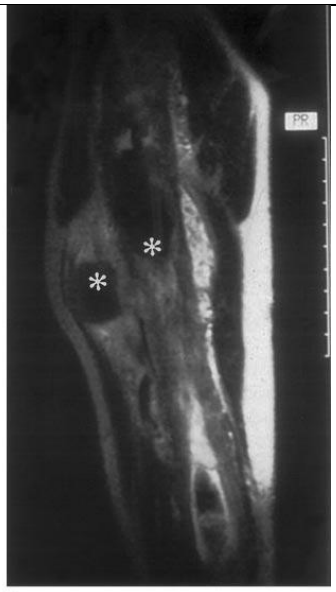
Ivory Vertebra





❖Complications of Paget Disease:

- **Bone Deformity:**
  - Long bones => Anterior or lateral bowing
  - Spine => Scoliosis
  - Pelvis => Protrusio acetabuli
- **Pathological fracture:**
  - Vertebral compression fracture
  - Banana fracture = horizontal cortical stress fracture in long bones; usually along convex border.
- **Secondary osteoarthritis:**
  - secondary to altered biomechanics and alignment across abnormal bone
  - Hip and knee involvement are most common
- **Neurologic Abnormalities:**
  - Spinal stenosis and foraminal encroachment: secondary to osseous expansion of the vertebral bodies, fractures of the spine, basilar invagination.
  - Calvarial enlargement can result in clinical complications related to cranial nerve compression
- **Neoplastic complications (Rare):**
  - **Sarcomatous transformation to:**
    - **Osteosarcoma**
    - **Malignant fibrous histiocytoma/ fibrosarcoma**
    - **Chondrosarcoma**
  - Giant cell tumors (benign and malignant) in skull and facial bones
  - Superimposed metastatic disease, multiple myeloma, leukemia, and lymphoma

Anterior bowing of tibia= Sabre tibia	Banana fracture	Vertebral compression fracture
2ry OA of hip	**Sarcomatous transformation to osteosarcoma**	
	a.  b.	

❖ *Nuclear medicine imaging*

- Isotope bone scintigraphy using a 99mTc-labelled bisphosphonate tracer is more sensitive but less specific than plain radiography for the identification of Paget's lesions.
- Increased homogeneous tracer uptake is seen secondary to the high perfusion of Pagetic bone and high affinity of the tracer to woven bone.
- Osteoporosis circumscripta may demonstrate a peripheral region of increased uptake and central photopaenia
- In the long bones, increased radiotracer uptake typically abuts one joint and extends into the diaphysis to a variable extent.

❖ *FDG PET/CT*

- Pagetic bone exhibits a variable degree of FDG uptake in up to one-third of patients.
- This may represent an obstacle when staging oncological patients with concurrent Paget's disease of bone, due to a potential overlap of imaging appearances of Pagetic bone with skeletal metastases.

Sarcoidosis

- Idiopathic systemic chronic granulomatous non-caseating disease of unknown etiology

- F > M
- Middle age
- Black > White

❖ Diagnosis

- Clinical + Radiological + Histological
- Biopsy: Transbronchial biopsy, CT-guided biopsy, or surgical biopsy
- Kveirn test
- Angiotensin-converting enzyme (ACE) level is commonly elevated and may correlate with disease activity

I- Thoracic Sarcoidosis

Pulmonary involvement in up to ***90%*** of patients with sarcoidosis

Stages (Silzbach Classification) & Typical HRCT features

- Stage 0: Normal (5%)
- Stage 1: Lymphadenopathy (50%): (Garland's triad)
    - Bilateral & symmetrical hilar lymphadenopathy
    - Mediastinal: Right paratracheal + Tracheobronchial + Azygos
    - Egg shell calcification (5%)
- Stage 2: Lymphadenopathy + Pulmonary infiltration (30%):

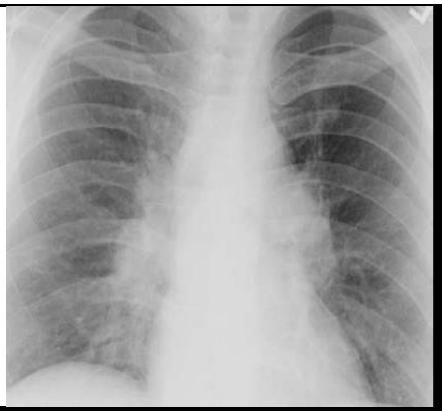
  Pattern: Reticulo-nodular infiltration
    - Nodules:
        - Micronodules (2–4 mm; well defined, bilateral)
        - Macronodules (≥5 mm, coalescing)
        - Lymphatic distribution: peribronchovascular, subpleural, interlobular septal
    - Fibrotic changes: reticular opacities, architectural distortion, traction bronchiectasis, bronchiolectasis, volume loss

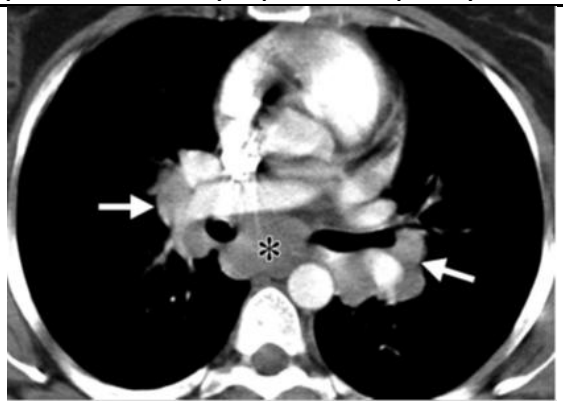
  Distribution: Predominant upper and middle lung zones
- Stage 3: Pulmonary infiltration + No lymphadenopathy (10%)
- Stage 4: Upper lobe pulmonary fibrosis ± Bullae - Fungal ball (5%)

Atypical features

- Lymphadenopathy: unilateral, isolated, anterior and posterior mediastinal
- Alveolar sarcoid pattern: Airspace consolidation – GGO
- Linear opacities: interlobular septal thickening, intralobular linear opacities
- Fibrocystic changes: cysts, bullae, blebs, emphysema, honeycomb-like opacities with upper- and middle-zone predominance
- Miliary opacities
- Airway involvement: mosaic attenuation pattern, tracheobronchial abnormalities, atelectasis
- Pleural disease: effusion, chylothorax, hemothorax, pneumothorax, pleural thickening, calcification, plaques
- Mycetoma, aspergilloma

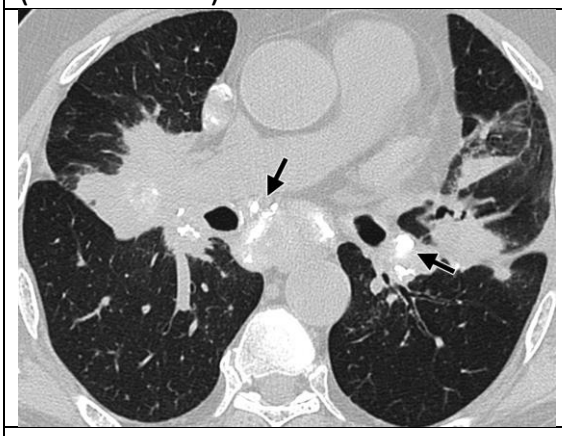
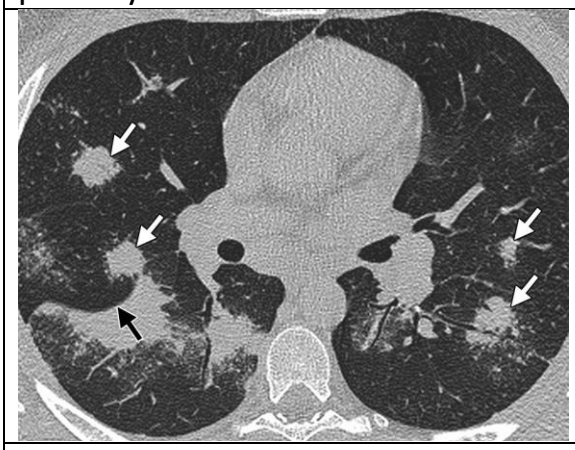
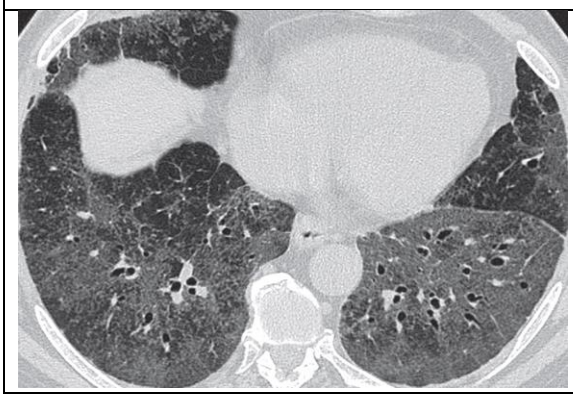
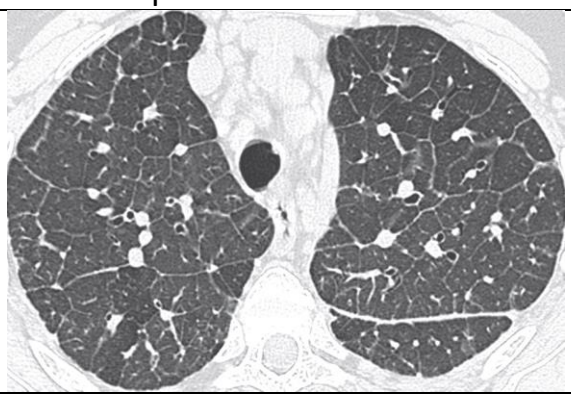
Garland's triad = Bilateral hilar + Right paratracheal lymphadenopathy





Reticulo-nodular pulmonary infiltration

UL pulmonary fibrosis + traction bronchiectasis + Bullae

Conglomerate masses and eggshell-like nodal calcifications (DD: Silicosis)	
	
Sarcoid galaxy sign = Fine nodular opacities around the large nodules (white arrows), Small low-attenuation spots that correspond to the spaces between partially coalescent small nodules	Alveolar sarcoid pattern of airspace consolidation
	
GGO	Reticular pattern
	

II- CNS Sarcoidosis:

1) Parenchymal: Periventricular deep WM lesions
2) Cranial Nerves: Facial Nerve Palsy
3) Leptomeningeal: thickening + enhancement
4) Neuroendocrine: Hypothalamus/pituitary enhancing lesions

III- Cardiac sarcoidosis

- Base of interventricular septum
- T2: high signal
- Delayed enhancement:
- Patchy transmural / subepicardial
- sparring subendocardial (DD: Infarction)

IV- Head & Neck Sarcoidosis

1) Parotid gland: Diffusely enlarged + High T2 signal + Enhancing
2) Lacrimal Glands: Diffusely enlarged + High T2 signal + Enhancing
3) Cervical LNs: Enlarged + Discrete

V- Upper Abdominal Sarcoidosis

1) Solid Organ: Hepatosplenomegaly + Multiple hypodense focal lesions (Spleen>Liver)
2) GIT: Gastric Antrum: Ulceration / Mural thickening / Linitis Plastica
3) Abdominal LNs: Retroperitoneal para-aortic LNs

VI- Genitourinary Sarcoidosis

1) Kidneys:
- Nephrocalcinosis: results from hypercalcimia
- Striated nephrogram: due to interstitial nephritis
- Multiple bilateral hypodense nodules (as Lymphoma)
2) Scrotum:
- Enlarged epididymis
- Testicular nodules: Hypoechoic & T2 Hypointens & Enhance

VII- MSK Sarcoidosis

1) Joints:

- Lofgren Syndrome (acute sarcoid) = Inflammatory arthralgia + Erythema nodosum + Mediastinal lymphadenopathy.

2) Skin:

- Lofgren Syndrome = Arthralgia + erythema nodosum
- Erythema nodosum: tender red bumps or nodules on the anterior aspects of the legs.

3) Muscles:

- Nodular Type = Sarcoid nodules: Central low T2 signal and peripheral high T2 signal
- Myopathic Type: Diffuse high T2 signal of muscles.

4) Bones:

- ***Phalanges of hands and feet.***
- ***Lacelike Honeycomb appearance***.
- Resorption of distal phalanges
- Sclerosis of terminal phalanges
- Subperiosteal cortical resorption along pharyngeal shafts
- Tenosynovitis.

Phakomatosis

Neurocutaneous Syndromes

- **NF-1**
- **Tuberous sclerosis**
- **Nail – Patella Syndrome**
- **McCune-Albright syndrome**
- **Nevoid BCC syndrome**

1- Neurofibromatosis Type – I

- Von Recklinghausen disease
- Multisystem neurocutaneous disorder
- Most common phakomatosis.
- Most common inherited CNS disorders
- Autosomal dominant disorders
- 50% inherited

Clinical diagnosis ≥ 2 of following are required:

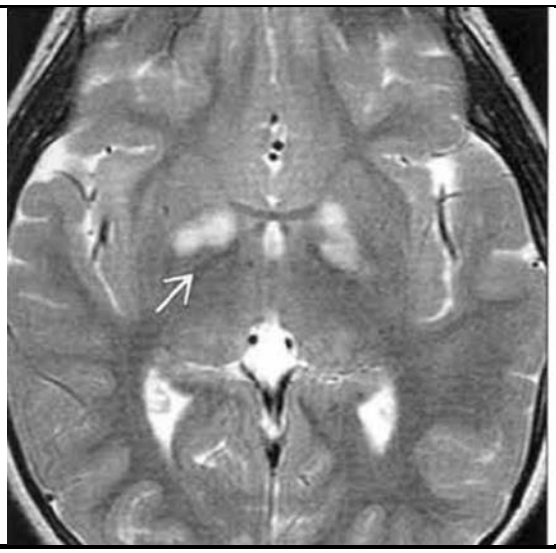
- ≥ 6 cafe au lait spots evident during one year
- ≥ 2 neurofibromas or 1 plexiform neurofibroma
- Optic nerve glioma
- Distinctive osseous lesion
- Sphenoid wing dysplasia
- Two or more iris hamartomas (Lisch nodules)
- Axillary or inguinal freckling
- Primary relative with NF-1

I- CNS Manifestations of NF-I

- FASI: focal areas of signal intensity in deep white matter and basal ganglia or corpus callosum i.e. areas of T2/FLAIR hyperintensity with no contrast enhancement
- Optic nerve glioma or optic pathway glioma
- Sphenoid wing dysplasia + Arachnoid cyst
- Buphthalmos
- Lambdoid suture defects
- Dural calcification at the vertex
- Moya-moya phenomenon (rare)

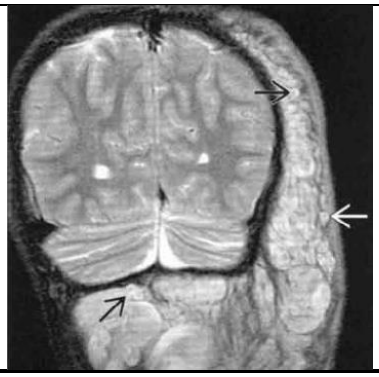
FASI:

- Focal areas of signal intensity in deep white matter and basal ganglia or corpus callosum
- T2/FLAIR: hyperintensity
- +C: no enhancement

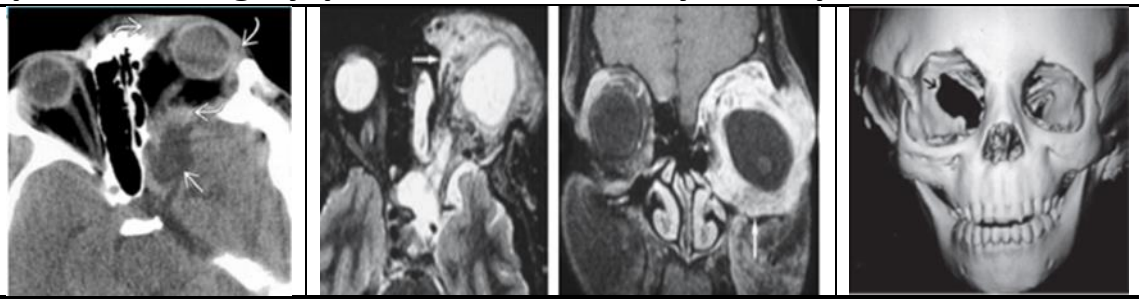


Optic Nerve Glioma

Plexiform Neurofibromatosis



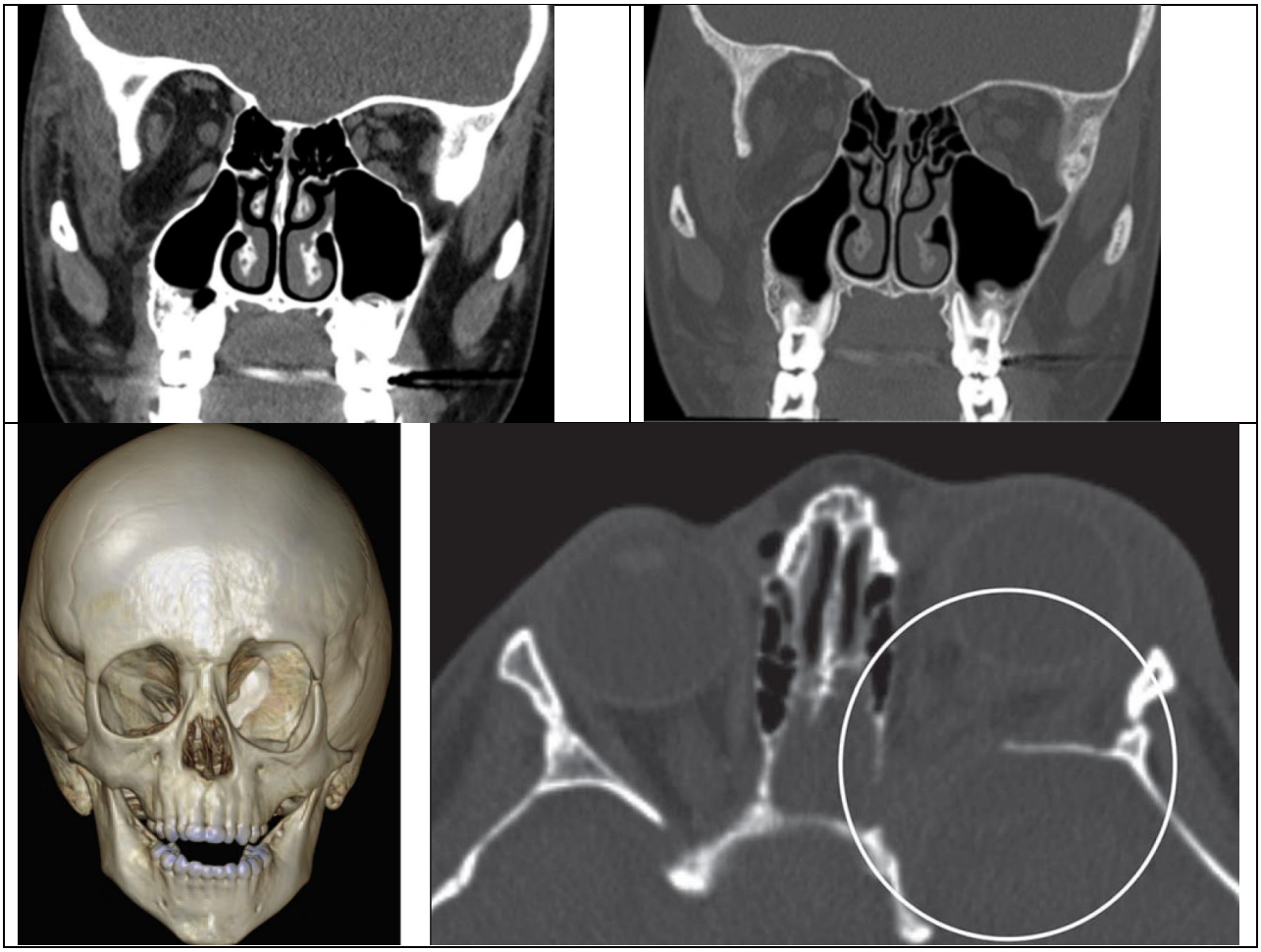
Sphenoid wing dysplasia + Arachnoid cyst + Buphthalmos



II- MSK manifestation of NF-1

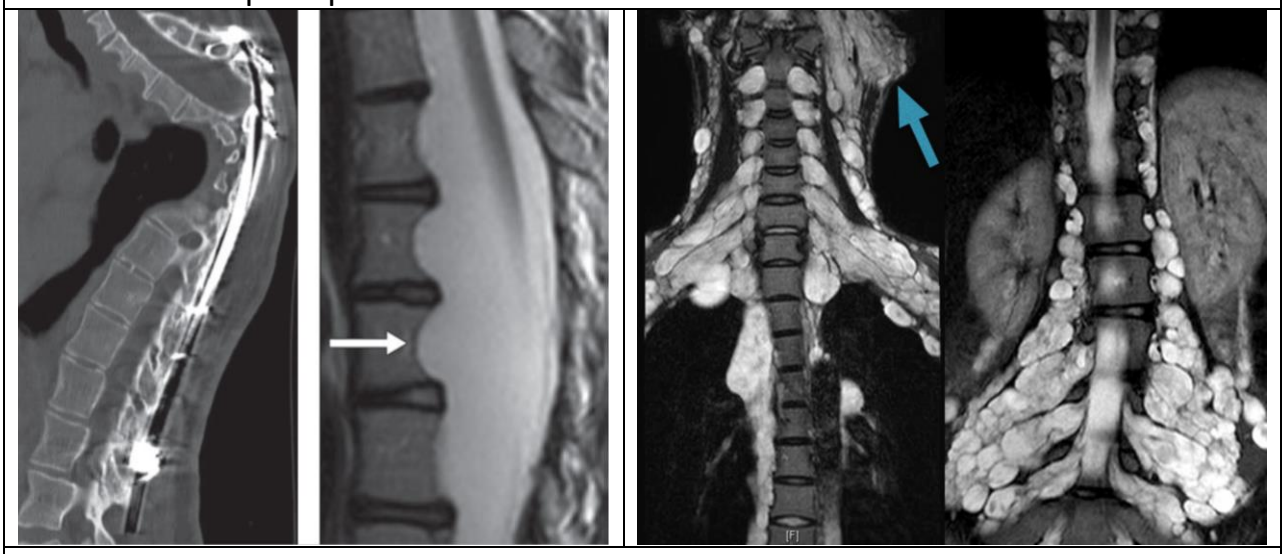
❖ ***Skull:***

- Macrocranium
- Lytic defects in cranium at lambdoid suture
- Enlarged foramina and IAC (due to neuromas and dural ectasia)
- Dysplasia of greater and lesser wings of sphenoid



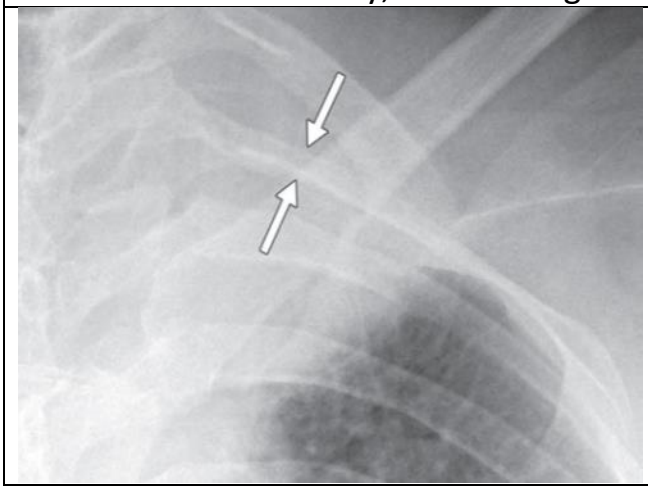
❖ ***Spine***

- kyphoscoliosis
- Vertebral body posterior scalloping
- Hypoplastic posterior elements: thinning of the pedicles, transverse processes, and lamina
- Transverse process spindling
- Enlarged neural foramina
    - Multiple neurofibromas (Dumbbell shaped)
    - Dural ectasia
    - Lateral meningocele
    - Paraspinal plexiform neurofibromatosis.



❖ ***Chest Wall:***

- Ribbon rib deformity, rib notching and dysplasia



❖ ***Long Bones:***

- Tibial pseudoarthrosis or, less commonly, ulnar pseudoarthrosis
- Bony dysplasias: especially affecting tibia
- Severe bowing: both lateral and anterior
- Multiple non-ossifying fibromas
- Multiple intra-osseous neurofibromas

❖ ***Skin and Soft Tissue Manifestations of NF1***

- Dermal neurofibromas appear as circumscribed masses on plain radiographs and on cross-sectional imaging

❖ ***Elephantiasis Neuromatosa***

- Limb hemihypertrophy = massive enlargement of the skin and soft tissues, often associated with plexiform neurofibromas and proliferation of nerve sheath fibromyxoid tissue

2- Tuberous Sclerosis

- Rare, Autosomal dominant (20%-50%) or sporadic (50%) or inherited (50%), neuroectodermal disorder.
- TS has been considered to be caused by mutations of two genes known as TSC1 and TSC2.

Major Features	Minor Features
Frequent	**Frequent**
Facial angiofibromas	Multiple pits in dental enamel
Hypomelanotic macules	Hamartomatous rectal polyps
Cortical tubers	
Subependymal nodules	
Common	**Common**
Retinal hamartomas	Bone cysts
LAM	Cerebral white matter radial migration lines
Renal AML	Multiple renal cysts
Cardiac rhabdomyomas	Gingival fibromas
Uncommon	**Uncommon**
Shagreen patches	"Confetti" skin lesions
Ungual fibromas	Retinal achromatic patches
Subependymal giant-cell tumors	

Definite diagnosis: two major features or one major feature plus two minor features
Probable diagnosis: one major feature plus one minor feature
Possible diagnosis: one major feature or two or more minor features

Age (y)	Main Causes of Death
0–9	Cardiovascular lesions, status epilepticus, bronchopneumonia
10–19	Brain tumors, renal failure, status epilepticus
20–29	Status epilepticus, renal failure, brain tumors
30–39	Renal failure, brain tumors, status epilepticus
40–49	Renal failure, LAM
>50	Renal failure, LAM

The clinical triad:

- Adenoma sebacum
- Seizures
- Mental retardation

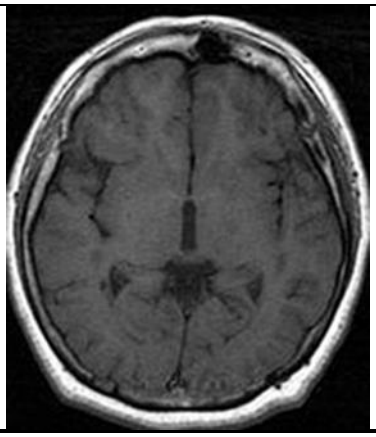
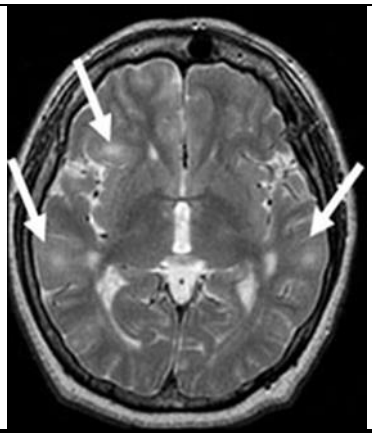
A- Dermatological features:

B- CNS Involvement (4 major CNS lesions)

1. **Cortical/subcortical tubers**
2. **Subependymal hamartoma (95-100%)**
3. **Subependymal giant cell astrocytoma (SGCA)**
4. **White matter lesions (40-90%)**

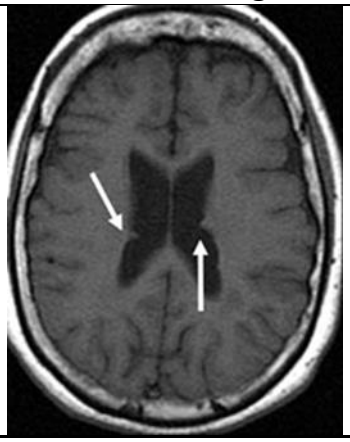
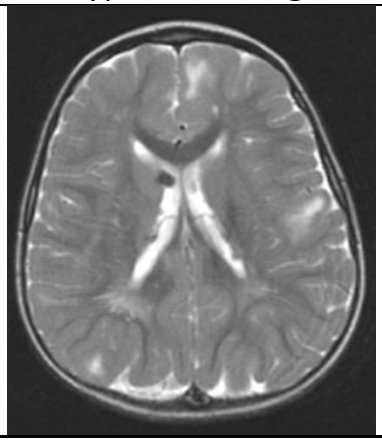
1) Cortical/subcortical tubers

- Multiple cortical and subcortical lesions
- Location: Supra>>>> infra tentorial
- Frontal> parietal> occipital> temporal> cerebellum
- CT : Ca^{++} with age
- T1+C: 10% of cortical tubers show enhancement
- MRS: Normal
- PWI: Hypovascular to WM

Axial T1:	**Axial T2:**	**Axial FLAIR:**
• The peripheral component is isointense to GM • The inner component is isointense to WM	• The peripheral component is isointense to GM • The inner component is hyper to WM	• The peripheral component is isointense to GM • The inner component is hyper to WM
		

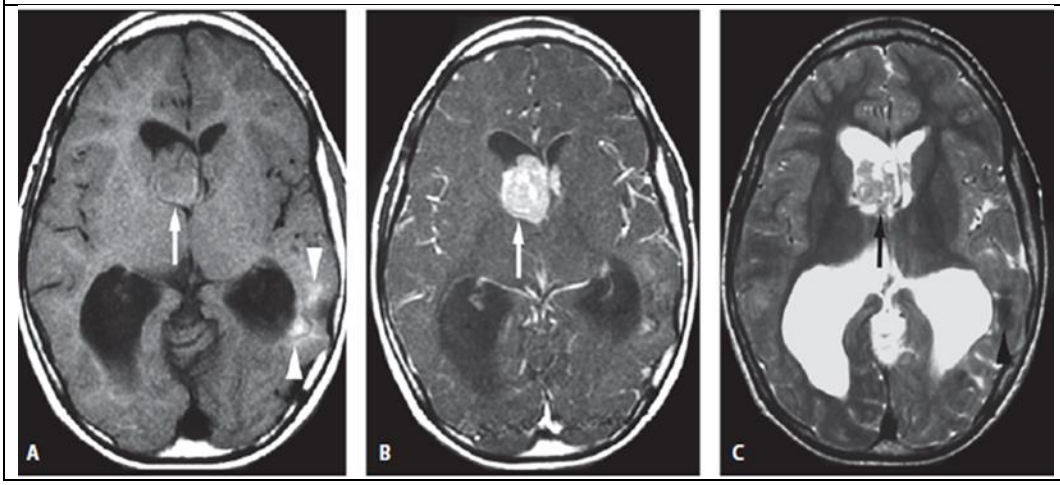
2) Subependymal Hamartoma

- Multiple subependymal nodules of 1-12mm
- CT: Ca ++ with age
- +C: May show minimal contrast enhancement

	T1: Isointense signal	T2: Hypointense signal
		

3) Subependymal Giant Cell Astrocytoma (SGCA)

- 15%
- WHO grade I
- Location: centered at foramen of Monro
- Size: Large > 1.2cm. Progressively enlarged
- Grow towards the ventricle not brain parenchyma
- Growth towards brain parenchyma suggests transformation to high grade.
- +C: Enhance



4) White Matter Lesions

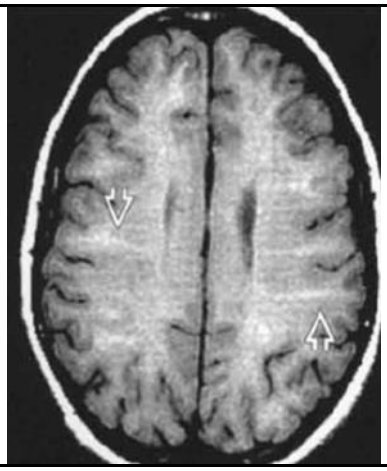
i. Superficial white matter abnormalities associated with cortical tubers
ii. Radial white matter bands
iii. Cyst like white matter lesions.

i. Superficial white matter abnormalities

- They are related to almost all cortical tubers.
- They reflect reduced myelin or increased gliotic reaction.
- T2: high-intensity areas
- T1: decreased-intensity areas

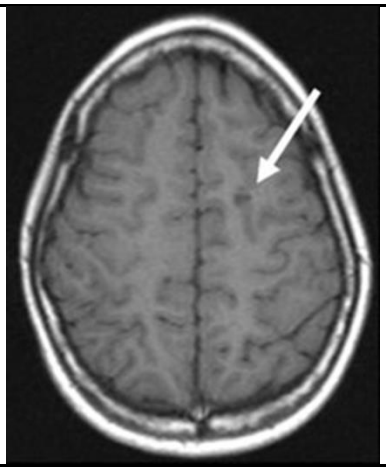
ii. Radial white matter bands:

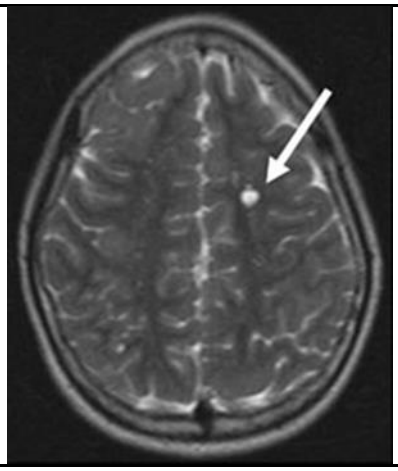
- Thin straight or curvilinear bands
- Run from ventricular or juxtaventricular white matter
- to the deep surface of cortical tubers or normal-appearing cortex



iii. Cyst-like white matter lesions (cystoid brain Degeneration)

- Small well-demarcated lesion of CSF like signal in all sequences are seen in white matter

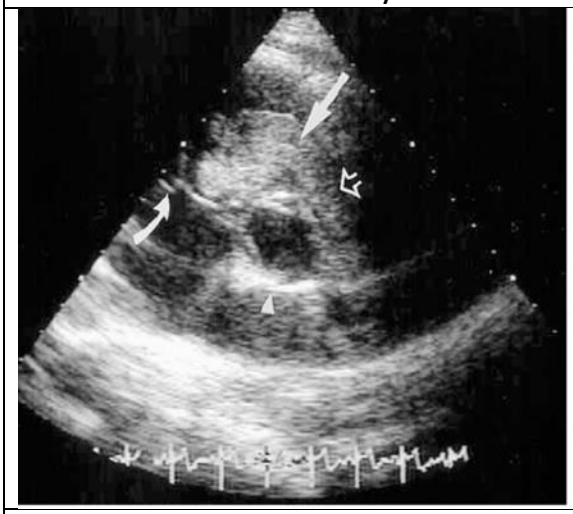


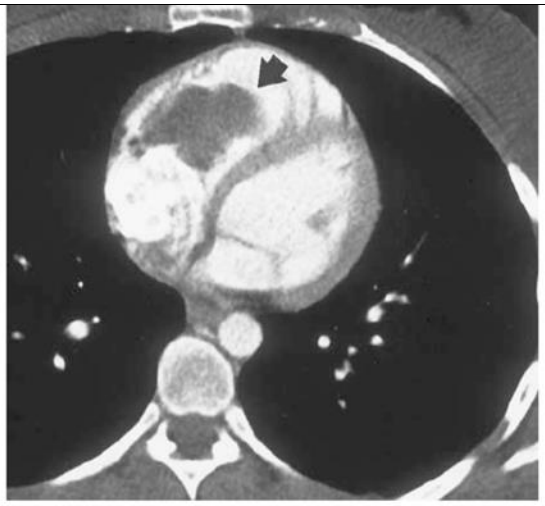


C- Cardiac Involvement

Cardiac Rhabdomyoma:

- Occur in 50-70% of pts with TS
- These harmatomas are usually multiple and intramural
- Most cardiac rhabdomyomas regress before birth.
- Spontaneous regression or disappearance of the tumor can occur in 70% of children by the age of 4 years.
- More than 80% of the tumors cause no clinical manifestations at birth.
- Only minority of cases cause abnormal valve function, outflow obstruction and arrhythmias





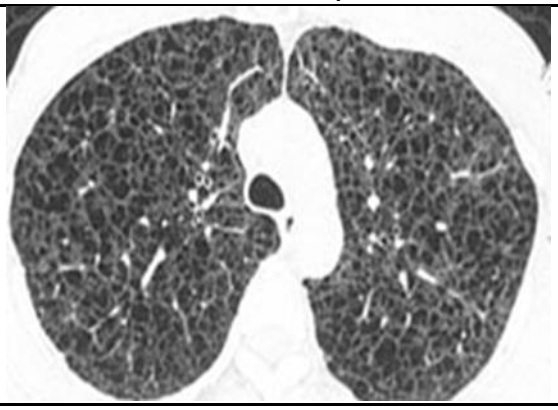
D- Eye Involvement

- Retinal hamartoma.
- Both eyes, multiple.
- May calcify: D.D: Retinoblastoma.

E- Pulmonary Involvement

Lymphangioleiomyomatosis (LAM):

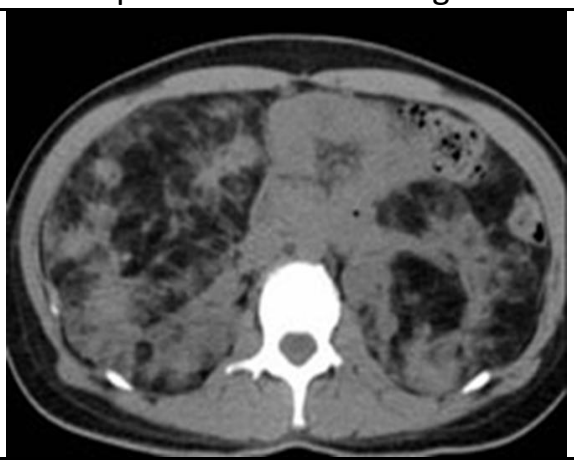
- Round, thin-walled cysts of variable size and contour
- Distribution: Symmetric and uniform throughout the lungs.
- Pneumothorax - Chylothorax

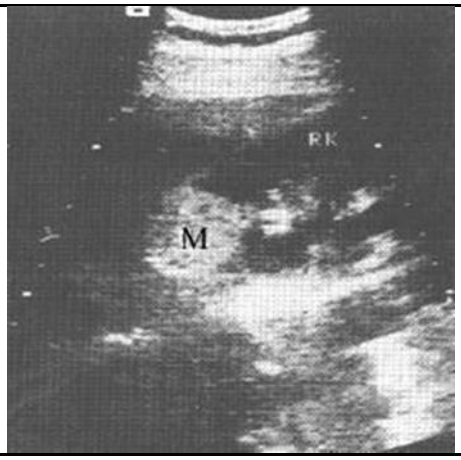


F- Renal & Retroperitoneal Involvement

1) Renal Angiomyolipoma:

- composed of fat, smooth muscles and aggregates of blood vessels.
- Usually large, multiple and bilateral
- US: Echogenic focal lesion
- CT: noncalcified cortical tumors containing fat
- Complication: Pseudo-aneurysms, intrarenal, perinephric, or retroperitoneal hemorrhage



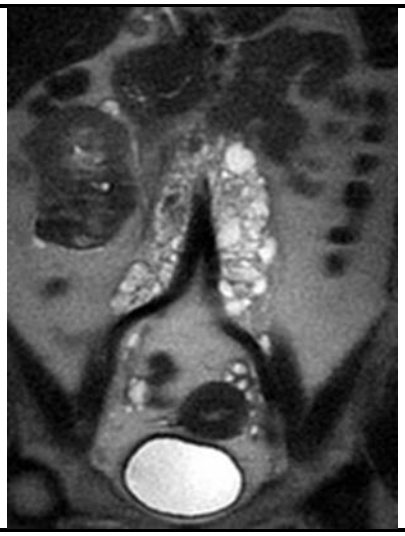


2) Multiple Renal Cysts:

3) Renal cell carcinoma:

4) Retroperitoneal LAM

- Thick- or thin-walled cystic lesions can be found in the retroperitoneum, which may reflect dilatation of lymph vessels due to obstruction

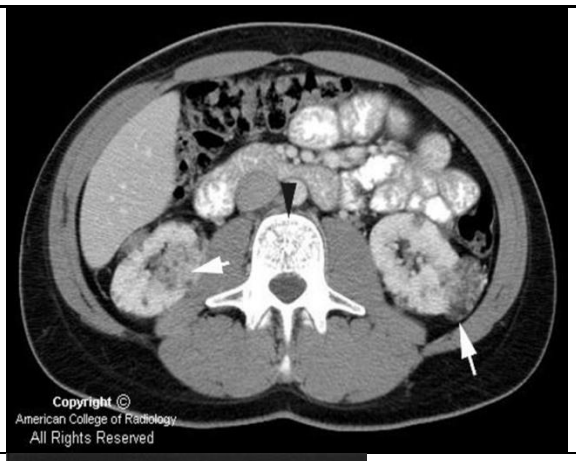


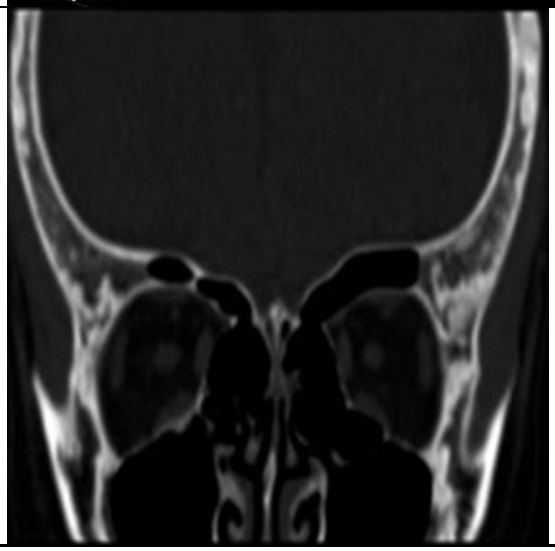
G- Hepatobiliary Involvement

- Hepatomegaly
- AMLs
- Lipomas
- Hamartomas
- Fibromas.

H- Skeletal Involvement

- Multiple bone islands: throughout the axial and appendicular skeleton.
- Cyst like lesions
- Hyperostosis of the inner table of the calvaria
- Osteoblastic changes
- Periosteal new bone formation
- Scoliosis.



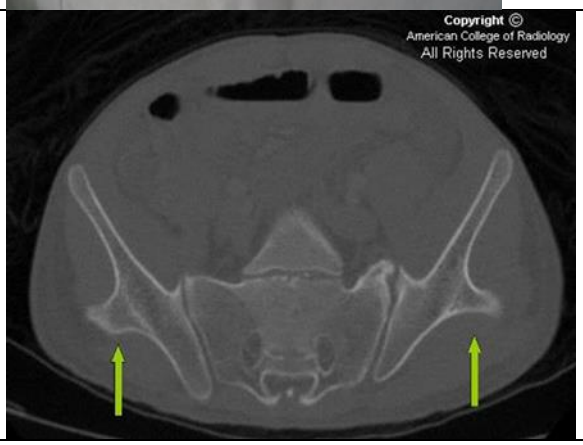


3- Nail Patella Syndrome (NPS)

- An autosomal-dominant condition caused by a mutation of the LMX1B gene.

Clinical Tetrad:

- Nail dysplasia: absent, hypoplastic, or split, or triangular lunula
- Patellae: may be absent or hypoplastic
- Iliac “horns”
- Elbow findings: bone abnormalities or pterygia (skin webs) leading to restricted range of motion or dislocation



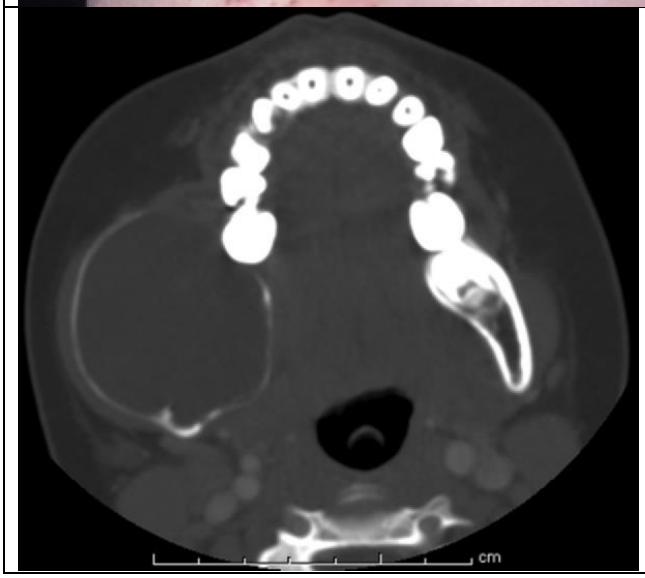
4- McCune-Albright Syndrome

- McCune-Albright syndrome is a nonhereditary phakomatosis that primarily affects females and is characterized by the triad of:
  - **Polyostotic fibrous dysplasia**
  - **Café-au-lait macules**
  - **Endocrine dysfunction**

Café-au-lait macules	**Polyostotic fibrous dysplasia**
Characteristic jagged (coast-of-Maine) borders on the trunk. Follow the lines of Blaschko, the embryologic lines of ectodermal migration Unilateral, occurring ipsilateral to skeletal lesions The abdominal lesion does not cross the midline.	Ground-glass matrix deforming the pelvis and proximal femora, Shepherd's crook deformity.

5- Nevoid BCC Syndrome / Gorlin-Goltz syndrome / Basal Cell Nevus Syndrome

- Autosomal dominant disorder.
- Patients are particularly sensitive to ionizing radiation; hence, their exposure should be minimized to prevent the development of BCCs in irradiated fields

Few up to hundreds of skin-colored, pink, or tan dome-shaped papules that may resemble benign nevi but are in fact BCCs	Palmar or plantar pits
	**<u>Odontogenic keratocyst</u>** Uni- or multiloculated cystic lesions More commonly in the mandible than in the maxilla **<u>occult rib abnormalities</u>** bifid, fused, hypoplastic, or splayed ribs **<u>Medulloblastoma</u>** **<u>Ovarian and cardiac fibromas</u>**

Skeletal Dysplasia

❖ Dysplasia of Axial Skeleton

Location	Examples
Skull	Achondroplasia, Cleidocranial dysplasia
Mandible	Pyknodysostosis
Clavicle	Cleidocranial dysplasia
Ribs	Asphyxiating thoracic dysplasia, Thanatophoric dysplasia
Spine	Spondyloepiphyseal dysplasia congenita, Mucopolysaccharidoses
Pelvis	Achondroplasia

❖ Dysplasia of Peripheral Skeleton

Location of abnormality	Examples
Epiphyseal	Chondrodysplasia punctata
	Spondyloepiphyseal dysplasia
Metaphyseal	Achondroplasia
	Chondroectodermal dysplasia
Diaphyseal	Progressive diaphyseal dysplasia
Combination	Spondylo-epimetaphyseal dysplasia
	Metatropic dysplasia
	Mucopolysaccharidoses

❖ Types of Dwarfism

Type of shortening	Examples
Rhizomelic	Achondroplasia
	Spondyloepiphyseal dysplasia congenita
Mesomelic	Mesomelic dysplasia
Acromelic	Acrodysostosis
Micromelic	Achondrogenesis

Dwarfism

- **Classification:**

Rhizomelic:

- **Proximal shortening (humerus or femur)**

Mesomelic:

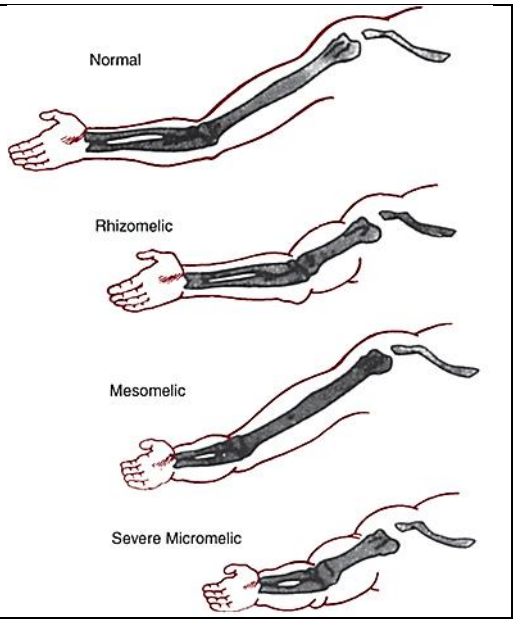
- **Middle shortening (tibia/fibula or radius/ulna)**

Acromelic:

- **Distal shortening (Hand)**

Micromelic

- **Entire limb shortening**



Rhizomelic	Mesomelic	Acromelic	Shortened trunk
• Achondroplasia • Thanatophoric • Chondrodysplasia punctate • Osteogenesis imperfecta 3 • Diastrophic dwarfism	• Dyschodrostoses	• Asphyxiating thoracic dystrophy • Pyknodysostosis	• Mucopolysaccharide

A- OSTEOGENESIS IMPERFECTA

- Heterogeneous group of a generalized connective tissue disorder leading to micromelic dwarfism characterized by:
  - Bone fragility
  - Blue sclera
  - Dentinogenesis imperfecta

- **<u>Osteogenesis imperfecta complications:</u>**
  - Impaired hearing / deafness from otosclerosis (20- 60%)
  - Death from intracranial hemorrhage (abnormal platelet function)

❖ Osteogenesis Imperfecta Tarda

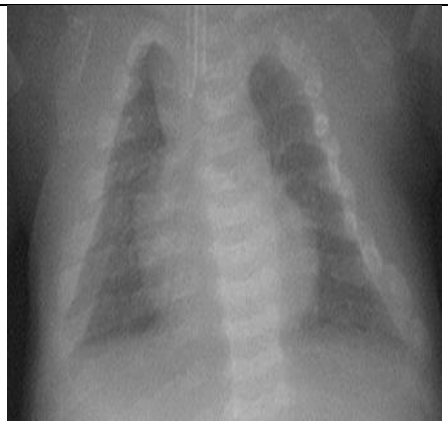
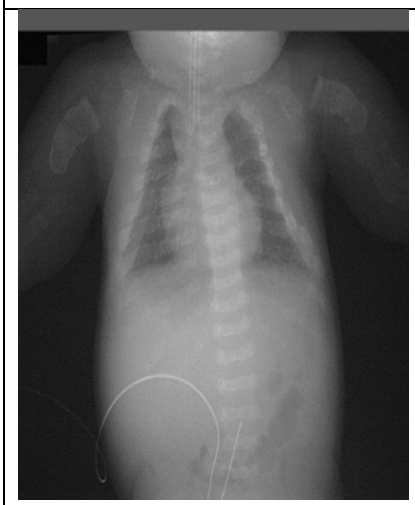
Type I	Type IV
AD; compatible with life	AD; mildest form with best prognosi's
<u>Clinical</u> Age at presentation: 2 6m Blue sclerae Presenile deafness Normal / abnormal dentinogenesis	**<u>Clinical</u>** Normal scleral color Little tendency to develop hearing loss
<u>X-ray</u> Infants of normal weight + length Osteoporosis Fractures in neonate (occurring during delivery)	**<u>X-ray</u>** Tubular bones of normal length; Osteoporosis Mild femoral bowing may occur
<u>Ob US:</u> Marked bowing of long bones No IUGR	**<u>Ob US:</u>** Bowing of long bones

❖ Osteogenesis Imperfecta Type II (Congenta)

- Perinatal lethal form
- most frequent variety

Clinical

- Blue sclera
- Ligamentous laxity + loose skin

Thin poorly ossified skull	Thin beaded ribs ± fractures resulting in ***Bell shaped narrow chest***
	
Spinal osteopenia	Shortened broad crumpled long bones Bone angulations, bowing, demineralization Localized bone thickening from callus formation (“***Accordion bones”)***
	

❖ Osteogenesis Imperfecta Type III

- Autosomal recessive / dominant; progressively deforming disorder compatible with life

Clinical

- Bluish sclerae during infancy which turn pale with time
- Joint hyperlaxity (50%)

OB US:

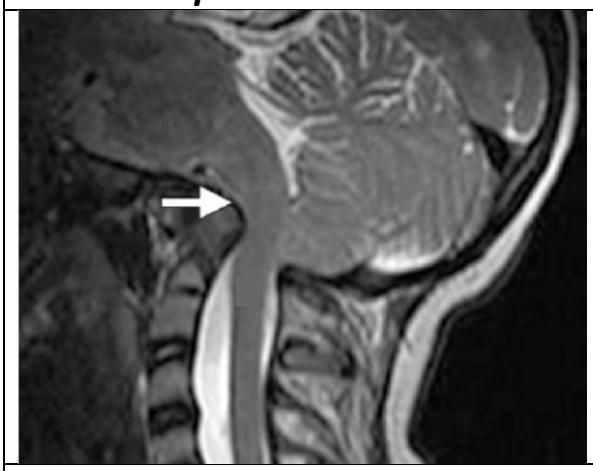
- Short + bowed long bones
- Fractures
- Humerus almost normal in shape
- Normal thoracic circumference

Skull

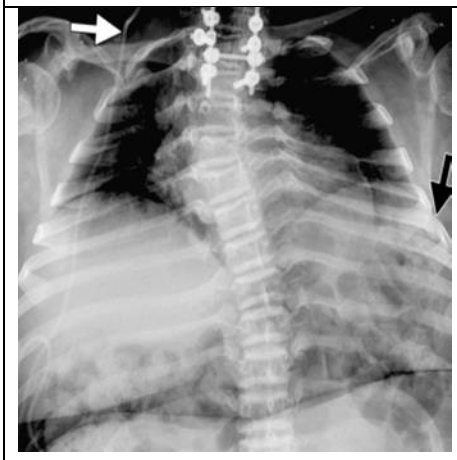
- Macrocranium
- Decreased ossification of skull
- Frontal bossing
- Flattening of the occiput
- Wide suture
- Multiple Warmian bones
- Basilar invagination

Multiple Wormian Bones

Flat Occipiut

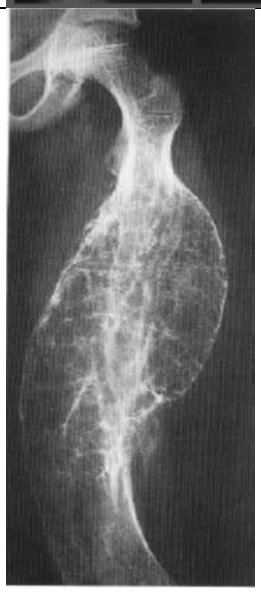
Basilar Impression	*Platybasia*
	

❖ **Spine**

Scoliosis	**Platyspondyly**	**“Codfish vertebrae”**
		

❖ **Normal pelvis**

❖ Long bone

Progressive deformities of limbs + spine into adulthood Shortened + bowed long bones	Thin cortex Diaphyseal overtubulation Fracture Flat foot Ostopenia
	

B-Thanatophoric Dysplasia

- Lethal skeletal dysplasia.
- 2nd most common lethal skeletal dysplasia after OI type II.

2 Sub types

- **Type I :**
  - Marked under development of skeleton, telephone handle femurs more pronounced.
- **Type II :**
  - The presence of a cloverleaf skull may be a distinctive feature
  - Limb shortening milder and bowing is not a feature

Limbs

- Proximal portions of the long limbs are small giving a rhizomelic appearance.
- Long limbs (typically humeri and femora) have a typical "telephone handle" bowing with metaphyseal flaring.

Chest

- Narrow chest
- Short horizontal ribs
- Small scapulae

Iliac bones

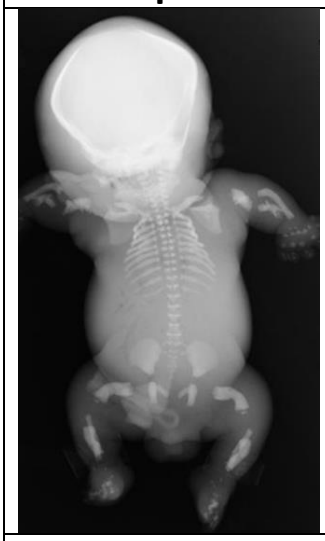
Usually hypoplastic
small squared iliac wings
may show a "trident" acetabular roof

Spine

- platyspondyly : flattening of vertebral bodies
- Normal trunk length

Skull:

- Relative macrocephaly
- Frontal bossing
- Proptosis
- Nasal bridge flattening
- Kleeblattschaedel, or cloverleaf skull

Bell shaped Chest	**Platyspondyly**
	
Telephone Handle Type I	Cloverleaf skull Type II

C-ACHONDROPLASIA

- Heterozygous achondroplasia
- Autosomal dominant / sporadic (80%) disease
- Defective endochondral bone formation; epiphyseal maturation + ossification unaffected
- Related to advanced paternal age
- Prototype of ***Rhizomelic Dwarfism***

Incidence:

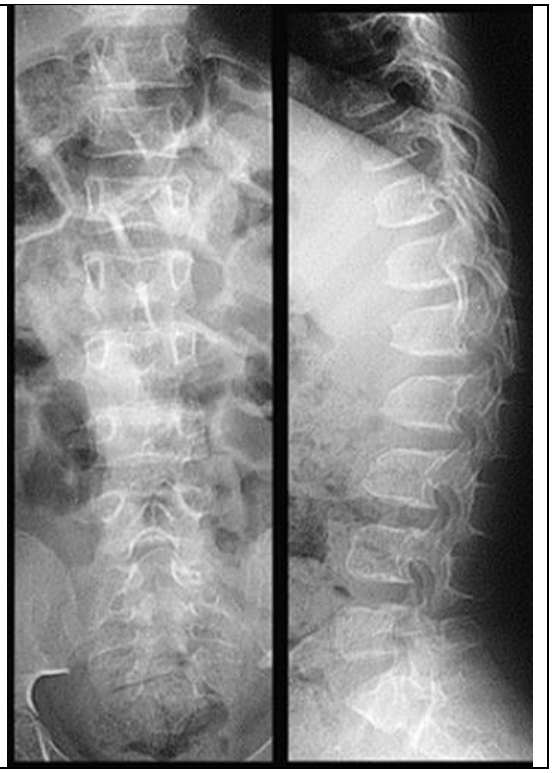
- Most common nonlethal bone dysplasia;
- M<f

Clinical Picture

- Normal intelligence + motor function
- Neurologic defects
- Classically circus dwarfs

Spine

- Spinal canal stenosis
- Decrease inter-pedicular distance (IPD) PROGRESSIVELY smaller lower in lumber (reversal of normal)
- Vertebral body: short, flat ,
- Bullet shaped
- Post. Scalloping
- Transverse Process;- short
- Kyphosis
- Cervical instability



Pelvis

- Square shaped flat nonflared pelvic bones with tombstone configuration
- Flattened iliac wings ("champagne glass")
- Horizontal acetabula (decreased acetabular angle)
- Small sacrosciatic notch
- Horizontal sacrum

Skull

- Skull base affected
- Clavirium not (formed by intramembranous bone)
- Shortened base of skull +
- Small facial bone
- Small foramen magnum
- Communicating hydrocephalus caused by obstruction of basal cisterns + aqueduct secondary to small foramen magnum
- Large calvarium with frontal bossing
- Broad mandible

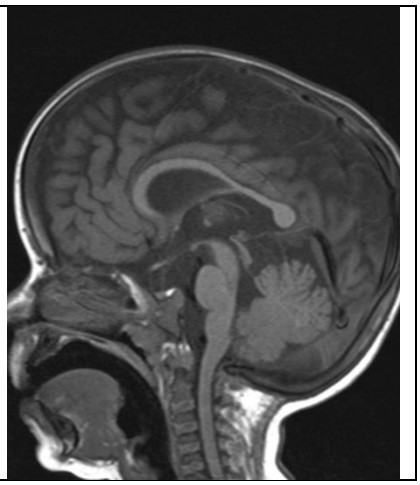
Facial

- Midfacial hypoplasia
- Relative mandibular prognathism
- Large tongue

LIMB	
Rhizomelic dwarfism = Proximal > Distal Femur + Humerus shortened	
➢ ***Ball in socket epiphysis*** + ➢ ***Broad V shaped metaphysis*** in which epiphysis is incorporated ➢ high position of fibular head (fibula less short) ➢ Short ulna with thick proximal + slender distal end	
<u>Hand:</u> ➢ ***Trident hand*** = inability to approximate 3rd + 4th finger ➢ ***Brachydactyly*** (uniform length of short bones) + divergent fingers ➢ ***Trumpet" appearance*** with short long bones but normal metaphyseal width	

Complications

- Hydrocephalus
- Syringomyelia (small foramen magnum)
- Neurologic complications (spinal cord comp
- Recurrent ear infection (poorly developed facial bones)
- Crowded dentition + malocclusion



D- Mucopolysacroidosis

- Lysosomal storage disorder from deficiency of specific lysosomal enzymes involved in degradation of mucopolysaccharides

i. Hurler Syndrome

Cause:

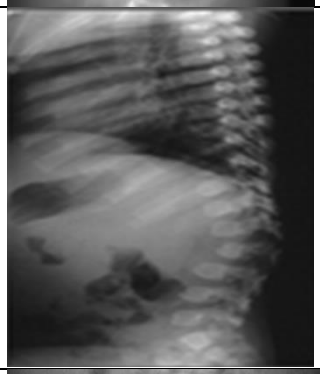
- Homozygous for MPS III gene with excess chondroitin sulfate B due to deficient X L iduronidase (= hurler corrective factor)

Clinical:

Age: usually appears >1st year
Dwarfism
Progressive mental deterioration after 1 3 years
Large head; sunken bridge of nose; hypertelorism
Early corneal clouding progressing to blindness
"Gargoyle" features = everted lips + protruding tongue
Teeth widely separated + poorly formed
Progressive narrowing of nasopharyngeal airway
Protuberant abdomen (secondary to dorsolumbar kyphosis + hepatosplenomegaly)
Urinary excretion of chondroitin sulfate B (dermatan sulphate) + heparan sulfate
Reilly bodies (metachromic granules) in white blood cells or bone marrow cell

Skull:

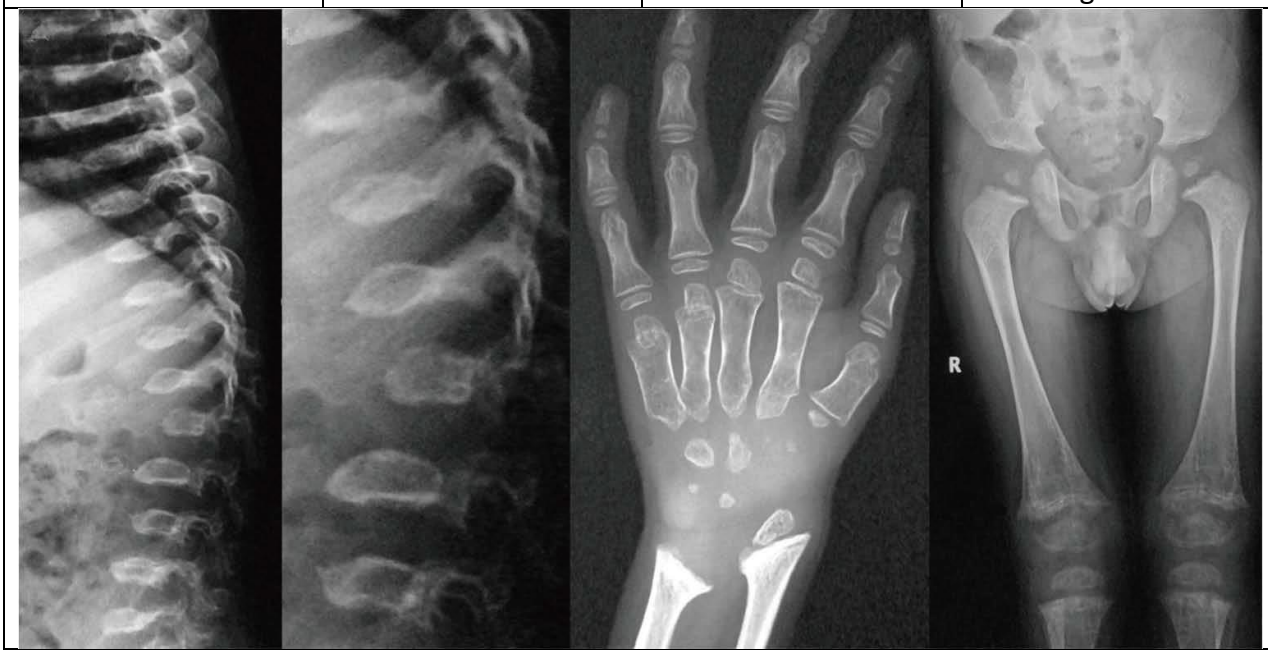
- (Earliest changes > 6 months of age)
- Scaphocephalic macropcephely
- Frontal bossing
- Calvarial thickening
- Premature fusion of sagittal + lambdoid sutures
- Deepening of optic chiasm
- Enlarged J shaped sella (undermining of anterior clinoid process)
- Small facial bones
- Wide mandibular angle + underdevelopment of condyles
- Atlanto-axial sublaxation

Extremities ➢ Thickening of diaphyses + tapering of either end: distal humerus, radius, ulna, proximal ends of metacarpals, ribs ➢ Enlargement of shaft due to dilatation of medullary canal with cortical thinning ➢ Deossification ➢ Flexion deformities of knees + hips ➢ Trident hands; clawing (occasionally) ➢ Delayed maturation of irregular carpal bones	
Chest Spatulate rib configuration Oar shape	
Spine ➢ Thoracolumbar kyphosis with lumbar gibbus ➢ Oval Vertebral Body ➢ ***Anteroinferior beak = Lower*** ➢ Long slender pedicle ➢ Short neck	
Pelvis: ➢ Widely flared iliac wings ➢ Constriction of iliac bones ➢ Coxa valga	

ii. Morquio Syndrome

- Normal intelligence
- Weakness + hypotonia
- Dwarfism with short trunk (<4 feet tall)
- Head thrust forward + sunken between high shoulders
- Corneal opacities evident around age 10
- Progressive deafness
- Short nose, wide mouth, spacing between teeth
- Semicrouching stance + knock knees from flexion deformities of knees + hips

Skull	**Chest**
• Mild dolichocephaly • Hypertelorism • Poor mastoid air cell development • Short nose + depression of bridge of nose prominent maxilla	• Increased A P diameter + marked pectus carinatum • Slight lordosis with wide short ribs • Bulbous costochondral junctions • Failure of fusion of sternal segments
Spine	
• Platyspondyly = universal vertebra plana (ddx: normal height in hurler syndrome) • Ovoid vertebral bodies • central anterior beak = Middle / tongue at lower thoracic / upper lumbar vertebrae • Mild gibbus at thoracolumbar transition = low dorsal kyphosis • Exaggerated lumbar lordosis • Widened intervertebral disc spaces	• Hypoplasia / absence of odontoid process of C2 • C1/C2 instability with anterior subluxation • Thick C2 body with narrowing of vertebral canal • Atlas close to occiput / posterior arch of C1 within foramen magnum
Hands & Feet • Short bones of forearm with widening of proximal ends • Delayed appearance + irregularity of carpal centers • Small irregular carpal bones • Proximally pointed short metacarpals • Enlarged joints; hand + foot deformities (flat feet) • Ulnar deviation of hand	**Pelvis** • "goblet shaped" /"wineglass" pelvis= constricted iliac bodies + elongated pelvic inlet + flared iliac wings • oblique hypoplastic acetabular roofs **Femur** • initially well formed femoral head epiphysis, involution + fragmentation by age 3 - 6 years • lateral subluxation of femoral heads; later hip dislocation • wide femoral neck + coxa valga deformity **Tibia** • delayed ossification of lateral proximal tibial epiphysis

Platyspondyly with maintained intervertebral disc height	Central beaking	proximal pointing of metacarpals	Delayed ossification of femoral heads, irregular epiphyses and secondary metaphyseal widening
			

E- Spondyloepiphyseal Dysplasia

- is a type of skeletal dysplasia that mainly involves the spine and proximal epiphyseal centers.

Two forms have been described:

Congenita:

- Abnormalities present at birth
- Due to abnormal synthesis of type 2 collagen

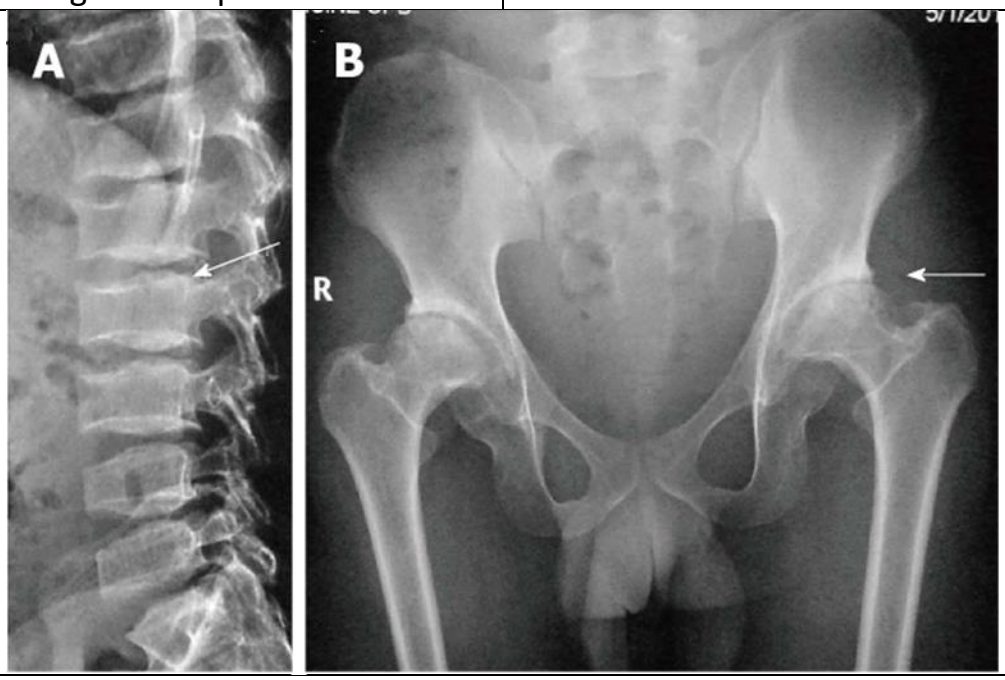
Tarda:

- Normal appearance at birth, short trunk becomes apparent in adolescence or adulthood

Clinical presentation

- Short neck
- Short trunk with protruding abdomen
- Normal IQ

Spine	Pelvis
• Platyspondyly • Posterior hump • Narrowing anterior portion of vertebral body • Narrowing of disc spaces.	Femoral head: flattening and late epiphyseal development Short necks and premature degenerative changes (arrow).



F- Multiple Epiphyseal Dysplasia

Dysplasia Epiphysealis Multiplex

- Bilateral symmetrical epiphyseal hypoplasia + irregularity
- Adjacent metaphyseal => Flarring + Irregularity
- Vertebral changes stimulating scheurmann's disease
- Irregular margins of the carpal bones, metacarpal and phalanges

G- Chondrodysplasia Epiphysealis Punctata

- ***Hallmark of epiphyseal calcific deposits***

H- Metaphyseal Chondrodysplasia

Sub types

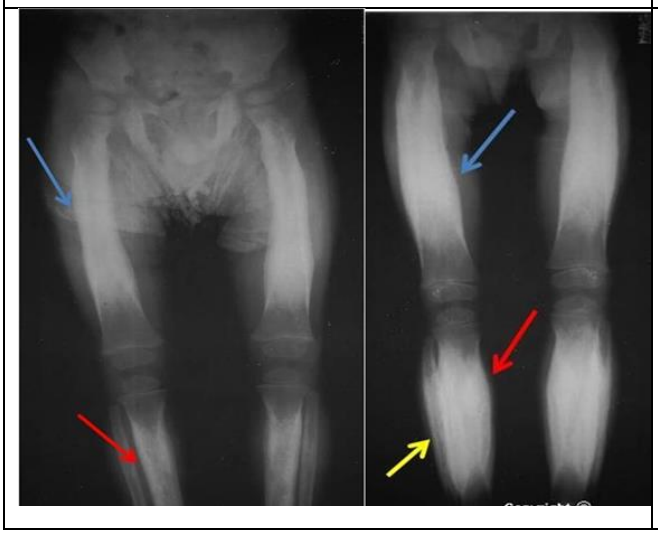
- Schmid type - mild type : metaphyses are cupped resembling ***Rickets***.
- Pena and Vaandrager type - intermediate type
- Jansen type - severe, irregular mineralisation in the metaphyses

I- Metaphyseal Dysplasia

- Metaphyseal dysplasia (also known as Pyle disease) is a rare autosomal recessive disorder characterised by flaring of the ends of long bones with relative constriction and sclerosis of the diaphysis and mild cranial sclerosis.
- It is one of the causes of an Erlenmeyer flask deformity. The flared metaphases are relatively lucent.
- The patients are often asymptomatic although genu valgus deformity may be a feature.
- Where there is cranial involvement, it is termed craniometaphyseal dysplasia.

J- Camurati-Engelmann Disease
Progressive Diaphyseal Dysplasia

- Rare bone autosomal dominant skeletal dysplasia
- **<u>Long bones:</u>**
    - Bilateral symmetric
    - Fusiform enlargement and sclerosis
    - Diaphyses of the lower extremities
    - Sparing metaphysis and epiphyses.
    - Cortical thickening
    - Progressive obliteration of the medullary cavity
    - Progression of the lesion along the axis of long bones.

Lower Limb	***Upper Limb***
	

K- Cleidocranial Dysplasia

- AD syndrome
- Delayed ossification of midline structures.
- Affects bones formed intramembraneously.
- The disease results in short stature

Skull

- Macrocephaly
- Brachycephalic.
- Wormian bones are common.
- Notice the wide sutures and lack of midline ossification
- Basilar invagination

Hands

- Accessory epiphyses of the metacarpals
- Terminal phalanges often are pointed with elongated second metacarpals.
- The radius may be hypoplastic.

Clavicle

Complete absence of the clavicles, (only 10%).

More often, only the lateral portions are absent.

Chest

- The thorax tends to be narrowed with delayed ossification of the sternum.
- The scapula tends to be small and high, and the glenoid fossae are small.
- The ribs are short and directed obliquely downward. Respiratory distress may occur in the newborn.
- The sternum is incompletely ossified.
- Failure of fusion of neural arches occurs, with delay in maturation of vertebral bodies, which retain an infantile biconvex shape.
- Supernumerary or bifid ribs also occur.

Pelvis

- Hypoplastic iliac bones
- Delayed ossification of the medial pubic bones
- Coxa vara deformity

Sclerosing Bony Dysplasia

- **Osteopetrosis**
- **Pyknodysostosis**
- **Craniodiaphyseal Dysplasia**
- **Melorheostsis**
- **Osteopoikilosis and Buschke-Ollendorff syndrome**
- **Osteopathia striata**
- **Chondrodysplasia Punctata and Conradi-Hünermann-Happle Syndrome**
- **Goltz syndrome**
- **Progressive diaphyseal dysplasia (Engelmann's disease)**
- **Hereditary multiple diaphyseal sclerosis (Ribbing disease)**
- **Hyperostosis Corticalis Generalisata**
- **Caffey's disease (infantile cortical hyperostosis)**
- **Idiopathic hypercalcaemia of infancy**

A- Osteopetrosis

- Heterogeneous group of genetic disorder characterized by increased bone density due to impaired bone resorption

- There is failure of resorption of the primary primitive fetal spongiosa by the vascular mesenchyme. This primitive bone has higher calcium content on ashing, and appears denser on radiology.
- The bone is brittle and fractures easily, but heals normally.

Types

i) Infantile Autosomal Recessive Type

- Failure to thrive
- Premature senility in facies
- Dental caries
- Anemia, leukocytopenia, thrombocytopenia
- Cranial nerve compression (optic atrophy, deafness)
- Hepatosplenomegaly (extramedullary hematopoiesis)
- Lymphadenopathy
- Subarachnoid hemorrhage may occur (due to thrombocytopenia)
- May be associated with:
- Renal tubular acidosis
- Cerebral calcification
- Prognosis: survival beyond middle age is uncommon (death due to recurrent infection, massive hemorrhage, terminal leukemia)

ii) Benign adult autosomal dominant type

- 50% asymptomatic
- Recurrent fractures
- Mild anemia
- Cranial nerve palsy (rarely)
- Prognosis: normal

Radiographic Findings:

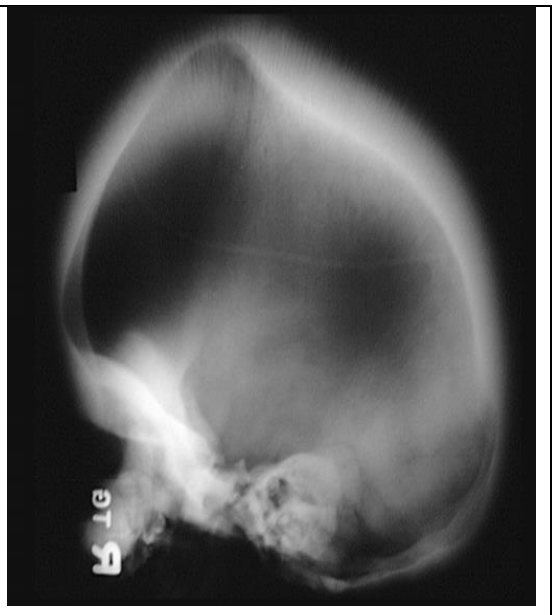
- Diffuse osteosclerosis
- Cortical thickening with medullary encroachment
- Erlenmeyer flask deformity = clublike long bones due to lack of tubulization + flaring of ends
- Bone-within-bone appearance
- "Sandwich" vertebrae=alternating sclerotic + radiolucent transverse metaphyseal lines (phalanges, iliac bones) indicate fluctuating course of disease
- Longitudinal metaphyseal striations
- Mandible least involved

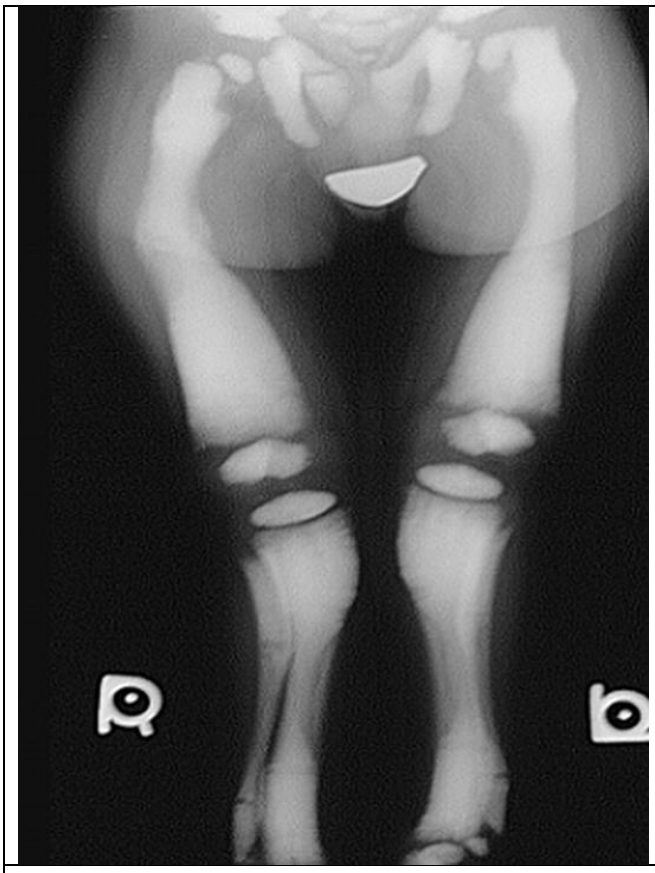
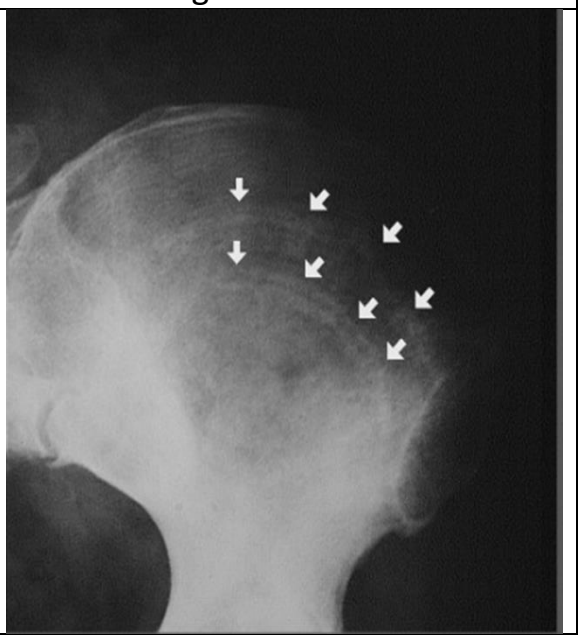
Complications:

- Fractures (common because of brittle bones) with abundant callus + normal healing
- Crowding of marrow (myelophthisic anemia + extramedullary hematopoiesis)
- Frequently terminates in acute leukemia

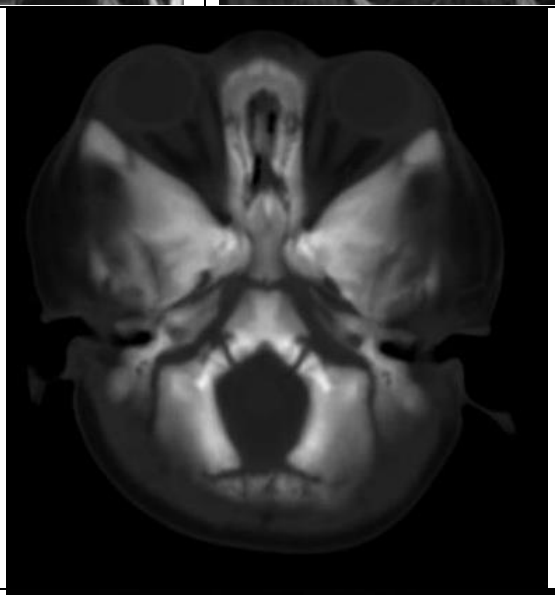
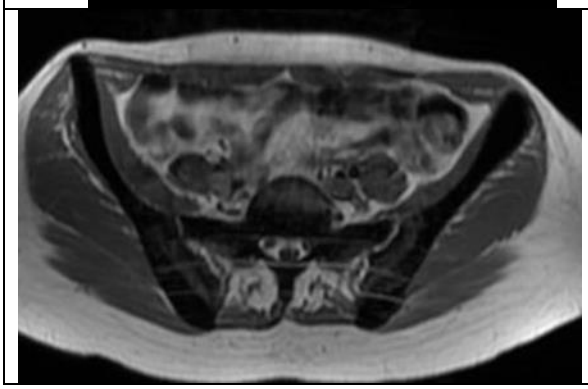
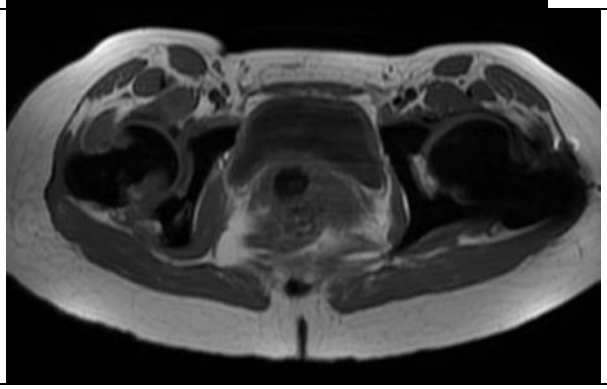
Skull:

- Macrocranium
- Thick dense skull base +- calvaria
- Obliteration of mastoid cells & paranasal sinuses.
- Narrowed neural basal foramina (inculding magnium) leading to CR nerve palsy
- Narrowed vascular basal foramina(carotid ,jugular) leading to CR nerve palsy
- Mandible :- retention of teeth caries, abcess
- Proptosis, hypertolerism



	
	Alternating sclerotic + radiolucent transverse metaphyseal lines (phalanges, iliac bones) as indicators of fluctuating course of disease
	

Sandwich vertebrae

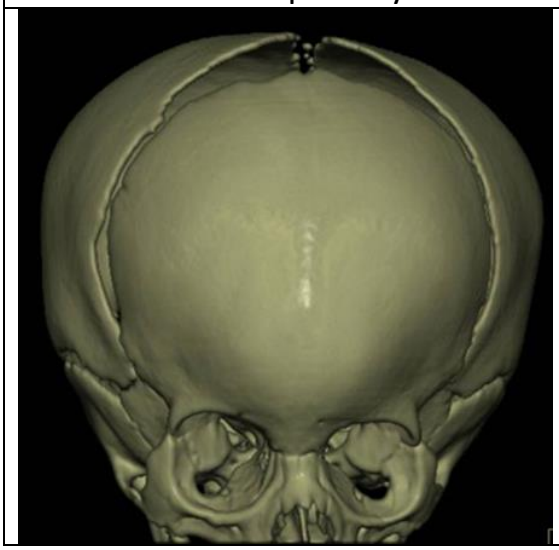




B- Pyknodysostosis

- Rare
- Autosomal recessive bone dysplasia
- Characterized by osteosclerosis and short stature.

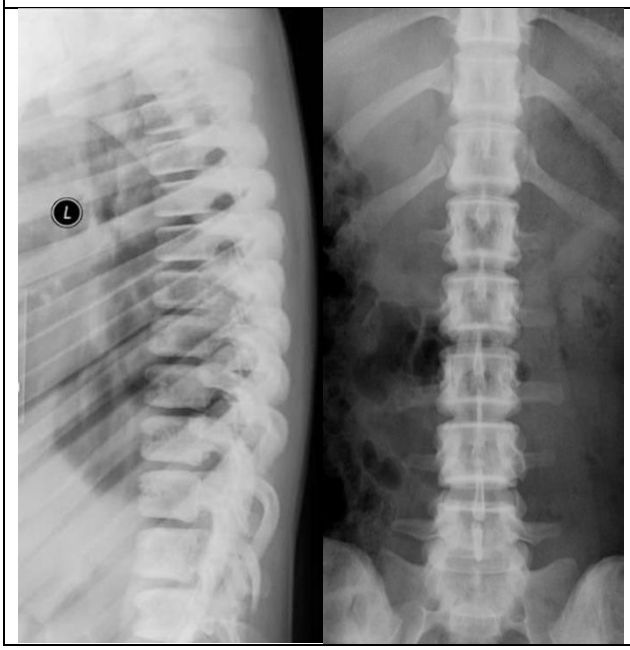
Skull

- Calvarial thickening
- Marked delay in sutural closure
- Frontoparietal bossing
- Wormian bones (lambdoidal region)
- Relative proptosis
- Nasal beaking
- Mandibular hypoplasia
- Obtuse mandibular gonial angle often with relative prognathism
- Persistence of primary teeth



Hands

- Short, stubby fingers
- Partial agenesis / aplasia of terminal phalanges simulating acro-osteolysis
- Delayed bone age

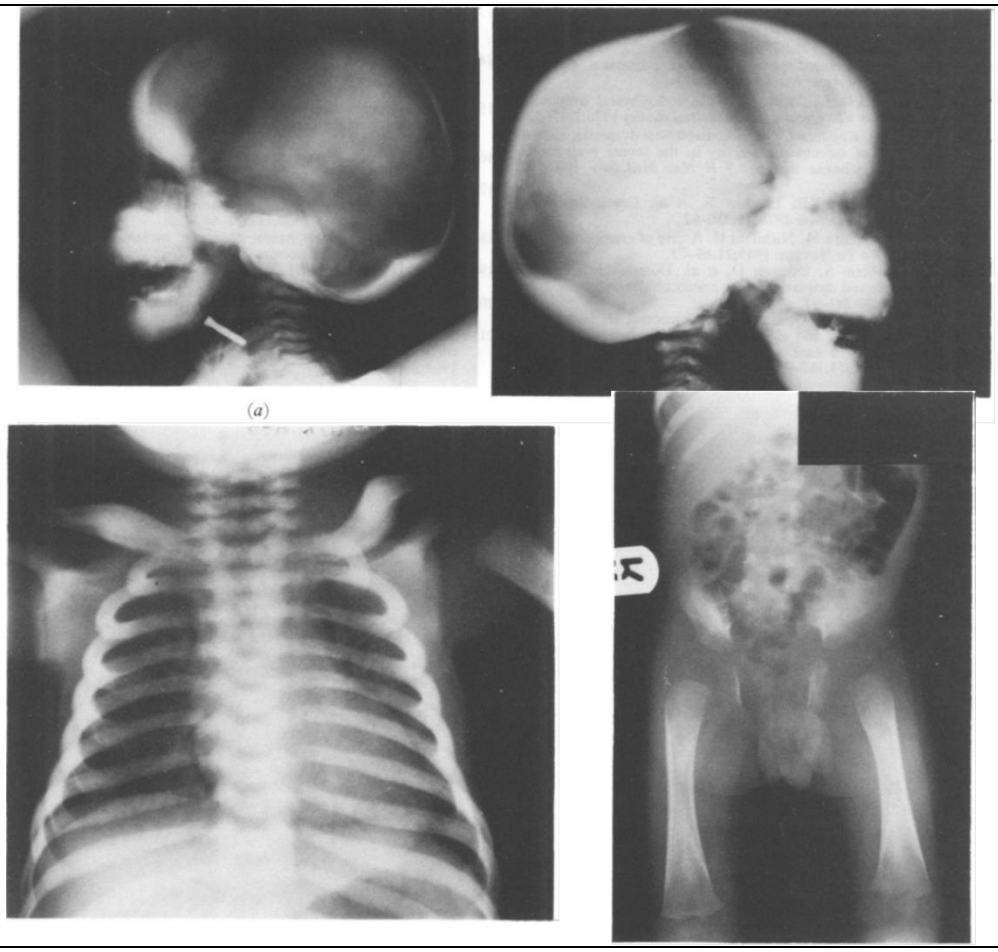
Spine:	***Long bones***
• Sclerosis of vertebral bodies • Dense vertebral bodies with characteristic sparing of the transverse processes • Increased lumbar lordosis • Vertebral segmentation anomalies particularly upper cervical and lower lumbar • Hypoplastic clavicles • Erosion of outer end of clavicles	• **Hyperostosis** • **Preservation of the medullary cavity.** • **A subacute fracture**
	

C- Craniodiaphyseal Dysplasia

- (also known as lionitis)
- Extremely rare autosomal recessive bone disorder
- causes calcium to build up in the skull, disfiguring the facial features and reducing life expectancy

Radiographic Findings:

The whole skull, including the facial bones and mandible, shows severe sclerosis and hyperostosis with nasal obstruction and obliteration of the sinuses.



D- Melorheostosis

- Melorheostosis (Leri's disease) is a rare, hyperostotic, nonfamilial, benign, sclerosing dysplasia of unknown cause, originally described by Leri and Joanny in 1922.

Radiological Findings:

- Contiguous/interrupted streaks of hyperostosis along the length of tubular bones gives the appearance of ***candle-wax dripping.***

E- Osteopoikilosis

Radiographic Findings:

- The typical findings on plain radiography are round or elliptical sclerotic foci

Distribution:

- Bilateral, but may be unilateral
- Long bones
- Small bones, such as the carpal/tarsal and metacarpal/tarsal bones.
- Pelvis and vertebrae.

Bone scan

- can be helpful in differentiating osteopoikilosis from bony metastases.

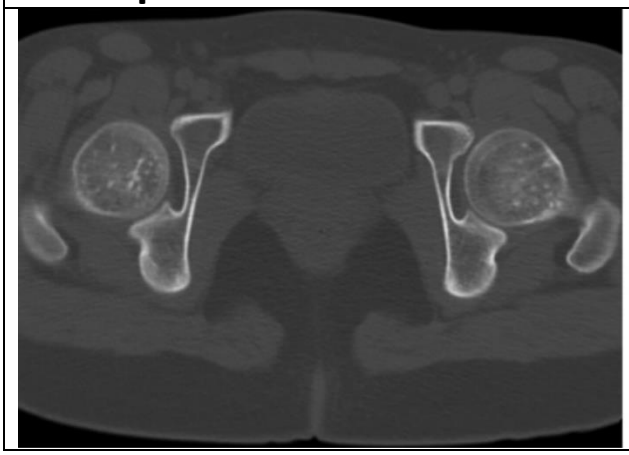
F- Osteopathia Striata

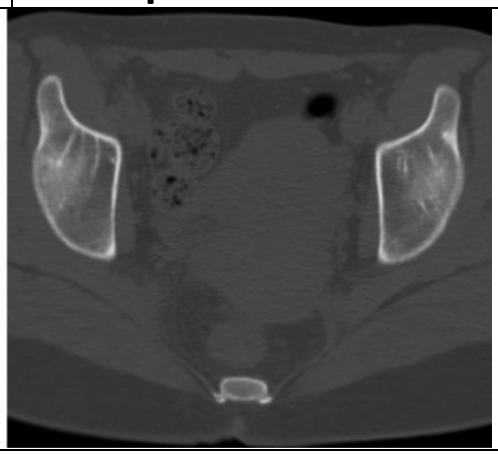
Radiographic Findings:

- Dense linear striations in the diaphyses and metaphyses of long and tubular bones.
- The striations run parallel to the long axis of the bone
- The striations can demonstrate a fan-shaped appearance due to the growth pattern of these bones

G- Overlap Syndrome

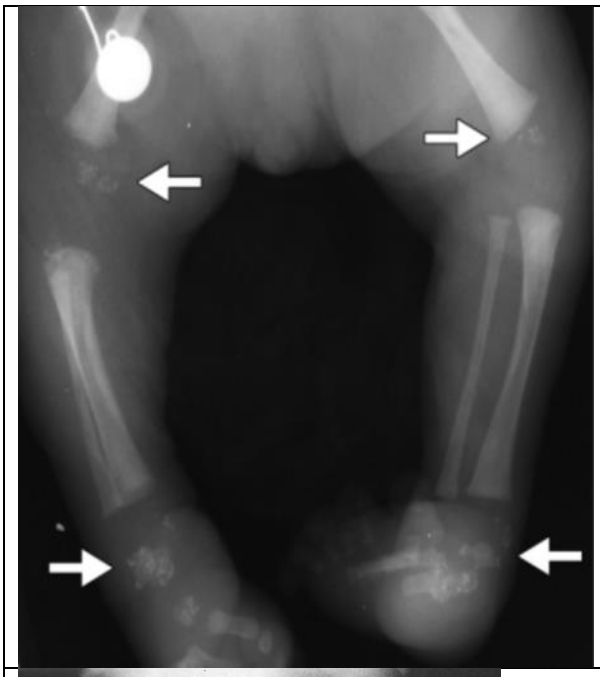
Osteopoikilosis	Osteopathia Striata

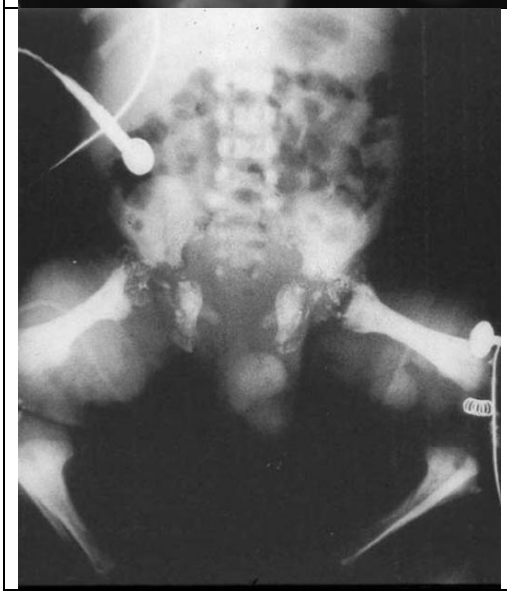




H- Chondrodysplasia Punctata

- Abnormal calcific foci in areas of enchondral bone formation.
- This "***epiphyseal stippling***" becomes radiographically visible in the epiphyseal cartilage prior to normal epiphyseal ossification





I- Caffey Disease

Infantile Cortical Hyperostosis

- Infantile cortical hyperostosis a largely self-limiting disorder which affects infants. It causes bone changes, soft-tissue swelling, and irritability.

Clinical picture:

- Children usually presents within first 6 months with swelling, erythema and irritability

Laboratory Findings:

- Erythrocyte sedimentation rate (ESR), C-reactive protein (CRP), and alkaline phosphatase (ALP) levels are often elevated.

Radiographic Findings:

- Lamellated periosteal reactions + Soft tissue swelling.
- Subperiosteal cortical hyperostosis
- Marked increase in cortical width and density
- Classic picture involves the ulna, clavicle or mandible.

Upper Limb: Ulna	Lower Limb